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A TEXT-BOOK OF ZOOLOGY

(FOR INTERMEDIATE AND MEDICAL STUDENTS)

By

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SECOND EDITION
REVISED AND ENLARGED
WITH 134 ILLUSTRATIONS
AND
ONE COLOUR-PLATE

THE BIOLOGICAL SUPPLIES
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FOREWORD

TO THE FIRST EDITION

Zoology as a subject in the university curriculum has been introduced comparatively recently in India, consequently there are as yet very few books dealing with the subject as taught in the Indian Universities.

Mr C John has written this book to meet the requirements of students preparing for the Intermediate examinations of the Indian universities He has followed the "type system," but has given particular attention to practical work Within the limits he has set himself, Mr John gives a clear and accurate account of the various types selected, and I hope the book will be appreciated and widely used by students of Elementary Zoology in all the Indian Universities

University of Lucknow K. N. BAHL,
Sept 5, 1938 D Sc. (Punj), D. Phil , D Sc. (Oxon)

PREFACE

TO THE FIRST EDITION

The purpose of the present work is to bring within the reach of the Intermediate students in Indian Colleges, a text-book of Zoology which covers their syllabus and at the same time gives full directions for their laboratory work Most of the books that are now available to the Indian student are either English or American, and are hardly suited for the syllabuses of of the Indian Universities and Intermediate Boards of Education, so much so that some of the Universities insist that their Boards of Studies prescribe not only the text books, but also the relevent chapters and pages therein, so as to get as near an approximation to the syllabus as possible There exists, therefore, the need for a text book of Zoology which is more or less confined to the Intermediate syllabus of some at least of the Indian Universities, and is at the same time not prohibitive from the point of view of price.

We have long since got over the practice of teaching Zoology merely by lectures and diagrams. It is now fully recognised that laboratory work is an important part of the study of scientific Zoology. However, even in these days there is a suspicion lurking in the minds of many a teacher of Zoology that practical work, though very essential, is subservient to theoretical work. The author believes that it is time we made a further step and considered the laboratory work as an integral part of the study and knitted together the theoretical and practical aspects of it into one inseparable whole Our modern laboratories, excellent for the purpose for which they are meant, and the often too large classes make this ideal rather difficult of realisation. Nothing, however, should prevent those teachers whose classes are very small from an attempt to combine laboratory work with lecture room work, doing away altogether with the separate provision made for lectures and practical in the time table.

In this book, I have made an attempt to make the practical and theoretical work of the student as closely related to each other as it is possible to do in a book, and if the book would help any one towards the realisation of this ideal in any degree, I would consider my labours amply rewarded.

A word may be said about the plan of the book Part I deals with the anatomy, physiology, histology and embryology of the easily obtained and easily handled vertebrate type, viz, the frog It is expected that this would give the elementary student a strong foundation on which to build step by step a knowledge of the remaining animal types in the natural order of their systematic position in the animal kingdom, beginning with Amoeba and ending with a mammal, viz, the rabbit Certain general considerations follow, rather than precede, the concrete study of the animal types, a knowledge of whose structure, functions and development is essential for a true grasp of these generalisations

I have had considerable difficulty in dealing with a subject so wide in its scope as Evolution and adapting it for the needs of the elementary student whose knowledge of general Zoology even at the end of his two years' course is not broad enough for an adequate grasp of the subject, and I have thought it best to treat it as briefly as possible consistent with the requirements of the syllabus.

The place of Human Physiology in an elementary text book which must include the rabbit as a type is rather anomalous There is but little of what the young student is expected to know of Physiology that he cannot gather from a study of the frog and the rabbit. Repetition of all that has been said under these types about digestion, respiration, circulation, excretion, the functions of the nervous system, sense organs, etc., would be mere waste. I have, therefore, accomodated Human Physiology for the sake of those Universities in whose syllabus it still finds a place, in the form of an Appendix with full references to the text wherever necessary so as to enable the student to read his Physiology portions as a connected whole.

No pains have been spared in emphasising the value of comparative study, as can be easily gathered from the fact that there are about twenty tabular comparisons as well as several sections dealing with comparative morphology.

"Meaning of the terms Biology, Morphology and Phisiology," one of those vestigial structures still persisting in our syllabuses has its proper place in a glossary, and the attention of the reader in this connection is directed to the Index and Glossary at the end of the book.

The illustrations have all been specially prepared for the book, some after well known authors, but most from original dissections and preparations In all, the parts are fully named, which I have no doubt, would be appreciated as a great convenience. For preparing the sketches for engraving I am very much indebted to Mr. A T. Joseph, one of my students, on whose skill and patient labour extending over an year much of the value of the book should depend I must also express my gratitude to my colleagues, Mr M A John, M. A, and Mr K T Kurien, B, A, for valuble assistance in the preparation of some of the dissections illustrated in the book Finally, I must acknowledge the invaluble help rendered by my friends, Dr K. N Bahl, D. Sc, D Phil.(Oxon), of the Lucknow University, Prof L P Mathur, M Sc, of St John's College, Agra, Dr C J George, M A., Ph D (London), D I C, Professor, Wilson College, Bombay, Dr K S Padmanabha Aiyer, M A., D. Sc., [Maharaja's College of Science, Trivandrum and M. R Ry S Pasupathi Ayyar, Avl, B A., L T, Lecturer, Kottayam College, and my sister, Miss A. Chacko, B A. L T, Dipl F. T (Birm), in reading through the book and for valuable corrections and criticism To Dr Bahl I am doubly indebted for his ready acquiescence with my request to write a foreword to the book

St Berchmans' College
Changanacherry
July 19, '38

C JOHN

PREFACE

TO THE SECOND EDITION

The very good reception accorded to the first edition both by teachers and students of Zoology, the fact that the entire edition has been sold out in such a short time and the very encouraging and appreciative comments of Zoologists all over the country justify the author and publishers in venturing into a second edition

The plan and purpose of the book remains unchanged, but it has been considerably enlarged and thoroughly revised to meet the requirements of most of the Universities and Boards of Intermediate Education as well as the Medical Colleges in India. A number of new chapters have been added on Parasitic Protozoa, Flat-worms, Round Worms, the Leech, Insects and Disease, the House-fly, Snakes and Variation and Heredity including Mendelism *Euglena* has been added to the Protozoan types and the External Morphology of a Bird to the Vertebrata

The vast majority of the diagrams have been redrawn and thirty-four new ones added including a tricolour frontispiece of a dissection of *Pheretima posthuma* Every care has been taken to ensure that the new diagrams do not repeat the draw-backs of the old.

The plan of interleaving for student's notes and diagrams having been abandoned, it has been possible to change the size of the book to Demi 8vo, a change which will be appreciated by everyone into whose hands the present edition may fall

Human Physiology which formed an appendix in the first edition has now been incorporated into the chapters on Mammalia, and I am indebted to Prof T C Joseph of Alwaye College for his suggestions and criticisms which provided the initiative for the change My warmest thanks are due to many other friends for their helpful and constructive remarks, but among them I must particularly mention Prof. G. E. Gates of Rangoon, whose criticism of the chapters on the earthworm has enabled me to recast them entirely, and Dr Padmanabha Aiyer of the University of Travancore for many a suggestion and much encouragement

The author trusts that in the new guise in which the book makes its entry into the arena of Indian Zoological Literature, it will be able to play an even better part than when it made its debut over two years ago.

Changanacherry,
March, 1941

C. JOHN

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PART I—THE FROG

CHAPTER I

AN EXTERNAL EXAMINATION

Material for Study A killed frog for each student, a few live frogs under bell jars

We shall begin the study of Zoology with an account of the structure, functions and life-history of the frog. The frog is well known to every child, and therefore the young student of Zoology has something familiar to begin with It is found in all parts of the world in large numbers, easily obtained in the laboratory and easily kept alive for a number of days without much attention It is large enough for dissection by the unskilled hand and observation by the unaided eye, but not so large as to make its dissection cumbersome. Besides, the frog is a vertebrate, that is, an animal with a backbone; and its structure, functions and life-history show many striking resemblances to those of man himself

1. The Head.—The head is foremost in locomotion, and its shape is such that the frog can easily cleave through the water while swimming, with least resistance All the important sense organs are placed on the head, as these are, as it were, the sentinels of the body. A pair of large **eyes** are prominent on the upper or dorsal side, much like our own in their make-up The portion of the eye that you can touch is the **cornea.** It is transparent and under it you can make out the **iris,** a coloured ring, surrounding a small, dark hole, the **pupil.** The **upper eyelid** is well developed, but not movable. The lower eyelid is less developed, but its edge is produced into a thin transparent membrane which can be drawn upwards over the eye. Poke the eye of a live frog with the handle of a scalpel and observe how this is done There is no doubt the frog can see even when the eye is thus closed This transparent eyelid is called the **nictitating membrane.** It is not unlikely that the eye is protected from the mud and dirt of the water in which the frog lives by drawing the nictitating membrane over it The red patch of tissue at the inner corner of the human eye is said to be a vestigial nictitating membrane. Have you seen any other animal which has the nictitating membrane well developed ? Just behind and slightly below the eye on each side is the **tympanic membrane** or ear drum It is a circular patch of skin easily distinguished from the surrounding portion by being tightly stretched over a circular rim of cartilage, not unlike the membrane of a drum We shall learn later (Sect 122) that this is the outermost part of the ear of the frog In the human ear the tympanic membrane lies at the bottom of the ear-pit, and is therefore not visible on the outside On the dorsal side of the head a little in front of the line joining the two eyes is a small lightly coloured median spot called the **brow-spot,** which is said to mark the position of a third eye possessed by the remote ancestors of the frog Near the tip of the snout on the dorsal surface are a pair of small openings called the **external nares** through which the frog breathes These evidently correspond to our own nostrils If you watch closely you can see a slight twitching of the nostrils at rather regular intervals What, do you think, this means ? The frog does not open its mouth except while feeding, but the **mouth opening** is easily seen between the **upper** and **lower jaws.** As we shall learn later, the frog cannot breathe through the mouth, and indeed it has to keep the mouth tightly shut while breathing Where the upper and lower jaws meet is the **angle of the jaw.**

2. The Trunk.—The frog has no neck, and the trunk with the head presents an outline not unlike that of a boat, a form most adapted for locomotion in water As the food is taken at the anterior or front end, so the undigested remains of the food or faecal matter and urine are passed out of the body at the posterior or hind end through the **cloacal aperture.** This can be seen between the thighs at the posterior end of the trunk dorsally In the squatting posture the frog has a well marked hump reminding you of a hunch-back

3. The Limbs.—The two pairs of limbs are very much like our own. Each **fore-limb** has an **upper arm,** a **fore arm** and a **hand** with four **digits** or fingers. Corresponding to these, each **hind-limb** has a **thigh,** a **shank** and a **foot** with five **digits** or toes Both the fore and hind limbs have a **rudimentary digit** which can be felt under the skin on the inner margin of the hand and the foot There are no claws on any of the digits In spite of their general resemblance, the fore and hind limbs differ a great deal from each other, The hind limb is several times as long and as stout as the fore limb, a fact which points to its greater usefulness as a locomotor organ. The **webs** between the toes make the hind limbs efficient swimming organs Note the ankle region of the frog Instead of a single joint, it shows two joints, one on the shank side and the other on the foot side This will be seen to better advantage when the skeleton of the animal is examined later (Sect 80) Each digit is made of a number of small parts jointed together The number of joints and the proportionate length of the various toes should be carefully noted and recorded On the ventral side of the toes you will notice a number of small round pads, one under each joint These are called the **subarticular pads.**

4. The Skin.—The skin is smooth and slimy You can easily understand how this is of use to the animal by trying to catch a large frog in your hand The skin of the dorsal side is thrown into a number of folds or **dermal plicae.** We shall learn in Sect 24 that the smooth moist skin enables the frog to breathe through it

Note the difference between the colouration of the dorsal and ventral surfaces While the colours vary among different frogs, all agree in that the upper side is darker than the lower You can easily understand how the darker colour of the back agrees more or less with the colour of the surroundings of the animal Remembering that the frog very often floats on the surface of the water, with only the external nares exposed, you can also suggest a reason for the lighter colouration of the ventral side

5. Sex Differences.— If you examine the several specimens in the class, you will notice that there are more than one species of frog All frogs are known to science by the *generic* name *Rana*, and the different kinds are denoted by the *specific* names such as *tigrina*, *hexadactyla*, etc Thus the large tiger-frog common all over India is *Rana tigrina* and a common South Indian frog is *Rana hexadactyla.* One species differs from another in colour, size and other factors, but primarily in that only individuals of the same species come together in sexual congress However, the sexes in one and the same species may differ considerably in size, colour or other factors, and it is possible to tell the male from the female often by an examination of mere external features You can look for external sexual characters in the specimens before you **Sexual dimorphism** may not be well marked in all species. The males are usually darker than the females, and may possess a hard horny swelling on the inner side of the first finger, especially during the breeding season Males are also usually smaller than the females In certain species the males possess loose folds of skin on either side of the throat immediately behind the angle of the jaw These are the **vocal sacs** which swell out while croaking and resonate the sound In certain other species both sexes possess them, while in yet others neither

6. Symmetry.—The frog's body, as you have no doubt noted, can be divided into two halves each the mirror image of the other. In other words the frog is **bilaterally symmetrical,** the two sides being the right and the left All vertebrate animals and most others are characterised by this symmetry In them we also distinguish a dorsal and a ventral side as well as an anterior and a posterior end

(1) Sketch the dorsal and the ventral views of the frog and mark the various parts printed in bold type Make the two figures side by side on the same page

All figures should be drawn to scale, in pencil, and the names of parts should be written around the figure

REVISION QUESTIONS

1 Describe the position of the eyes, fore limbs, mouth, cloacal aperture and the brow spot, using the terms anterior, posterior, dorsal, ventral, right, left, lateral and median

2 Compare the length of the hind limb of the frog with that of the head and body together

3 What are the various joints in the human limbs? Mark the corresponding joints of the frog in the sketch

4 Have you ever been startled by a frog leaping into a pond as you were walking by it? How did the frog escape your observation?

5 How many different species of frogs are there in your locality? Ask your teacher for their specific names

6. Enumerate the adaptations in the external characters of the frog for life in water and for life on land

7 Which of the fingers and toes of the frog correspond to your thumb and big toe?

8. How far does the external form of the frog resemble that of man?

9 What kind of symmetry do you find in a snake and in a star-fish?

10. Observe and make a note of the movements of the throat, flanks and nostrils of a frog quietly squatting under a bell jar

CHAPTER 2

GENERAL INTERNAL ANATOMY—THE ALIMENTARY CANAL—FOOD OF THE FROG

Material for Study A killed frog for each student, the skull of a frog

7. The Task before Us.—We have examined some of the external characters of the frog, and seen that these characters well befit the animal in its everyday life We have also noted the mouth opening through which the animal feeds, the nostrils through which it breathes, the cloacal aperture through which the faecal matter, germ cells, and urine are passed out, the sense organs like the eyes and ears which enable it to know and discriminate These suggest to us that there are certain internal *organs* which perform the *functions* of feeding, breathing, etc In the chapters that follow we shall try to see the relation between the several organs of the body and the functions which they perform

8. Dissection of the Abdominal Viscera.—(Figs 1 & 2) Lay the frog on the dissecting board ventral side up, stretch the limbs towards the corners of the board, and nail them to the board so that the heads of the nails are turned away from the centre of the board Cut the skin along the mid-ventral line (marked by the broken line in Fig 1) with a pair of scissors

Practical work

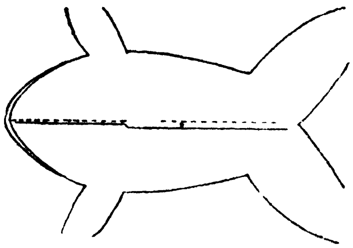

Fig 1 To show the line along which the skin and body wall are to be cut

Note that the skin is loosely attached to the body, and that there are large **sub-cutaneous lymph spaces** containing a clear fluid or **lymph.** The skin is attached to the body wall by narrow **septa** or partitions. Under the skin is the **body wall** which is made of muscle Red irregular branching lines on the inside of the skin and on the body wall are small **blood vessels.** A pink streak is seen along the middle line and indicates the presence of a blood vessel inside the body wall

Now proceed to cut open the body wall taking care to cut a little to one side of the pink line (as shown by the unbroken line in Fig 1) lest you cut the blood vessel marked by the pink line In front of it, the cut must pass along the mid-ventral line Cut as straight and neat as possible up to the snout Turn the flaps aside and pin them down The pink line marks the **abdominal vein.** Detach it from the body wall with the help of a needle without puncturing It enters anteriorly into a darkish red body, the **liver.**

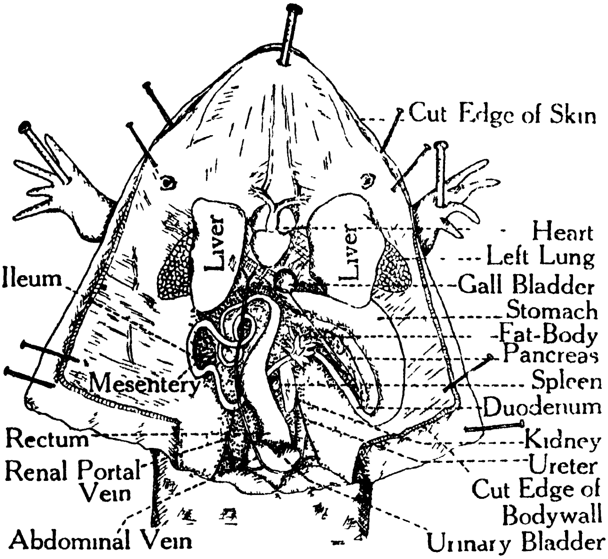

Fig 2 The abdominal viscera of the frog, dissected from the ventral side

The large space in which the liver and other viscera lie is the **coelom** or abdominal cavity containing lymph or coelomic fluid. It contains in addition to the liver, the following organs —the **heart** which in a recently killed frog will still be beating, the **alimentary canal** or food passage, a long coiled tube, the **lungs** and the **urinary bladder.** Pass a blow-pipe through the glottis (See Fig 4) and blow till the lungs are swollen Withdraw the blow-pipe Do the lungs collapse? If not, why? Prick one of the lungs with a needle What happens? Now pass the blow-pipe through the cloacal aperture and blow till the urinary bladder is swollen Note its shape and how it is attached to the adjoining parts of the body.

The more dorsally placed organs come into view when the alimentary canal is pushed aside These are the **kidneys,** the **fat bodies,** the **testes** in the male, the **ovaries** and **oviducts** in the female.

Pull the coiled portion of the alimentary canal up with a pair of forceps, and note that it is attached to the dorsal side of the body wall by a thin membrane, called the **mesentery,** in which lie many **blood vessels** and a small, round, reddish body called the **spleen.** On close examination it will be seen that the spleen is held between two folds of membrane as shown in Fig 3 This membrane forms a lining of the coelomic space and is called **coelomic epithelium** or **peritoneum.** The mesentery is thus made up of a double fold of peritoneum The organs in the abdominal cavity are therefore not free, but attached by the mesentery and other similar folds of membrane to the body wall dorsally

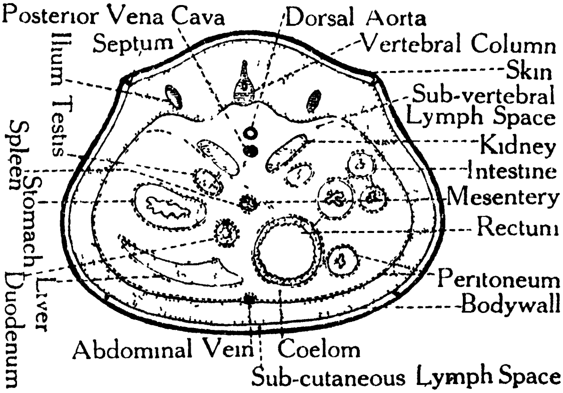

Fig 3 A diagrammatic transverse section of the frog across the kidney region

(2) Sketch an outline of the frog's body and mark in it all the parts printed in bold type in Sect 8

9. The Alimentary Canal. We have already seen the alimentary canal lying in the abdomen We must now make a more detailed examination of the organs of digestion, including the food capturing organs and the digestive glands They are concerned with the taking in, digestion and absorption of the animal's food For convenience we shall divide the entire system into three parts the mouth cavity, the alimentary canal and the digestive glands.

Practical work

10. Examination of the Mouth Cavity (Buccal Cavity). — (Fig 4) Open the mouth as wide as possible, and keep the jaws apart by means of a short stick held between their tips Wash the mouth cavity clean in running water

Now push a seeker into the depth of the mouth **(pharynx)** and note that it passes into a tube called **oesophagus.** Examine closely below (ventral to) the point where the seeker is inserted and look for a flat oval area with a slit-like vertical opening called the **glottis.** Pass bristles into the external nares and note the **internal nares** through which they enter the mouth Immediately behind each angle of the jaw is a fairly large opening called the **Eustachian recess.** Insert a seeker into the Eustachian canal and note how its point pushes against the inside of the tympanic membrane In some of the specimens in the class may be noted the **openings of the vocal sacs** immediately below the angles of the jaw A blow-pipe may be inserted into the opening and the sac blown out Pass your finger along the margin of the jaws and note the position and arrangement of the teeth. Also note the two small ridges of teeth on the roof of the mouth between the two nares The teeth on the upper jaw are called the **maxillary teeth** and those on the roof of the mouth, the **vomerine teeth.** Press down one of the eyes and note how the eye-ball pushes on the roof of the mouth, disclosing a large vacuity for the eye. Examine a prepared skull of the frog to see these vacuities better The **tongue** is on the floor of the mouth Note that it is attached near the tip of the jaw. Pull the tongue forwards and see its bifid end. It is very soft and sticky

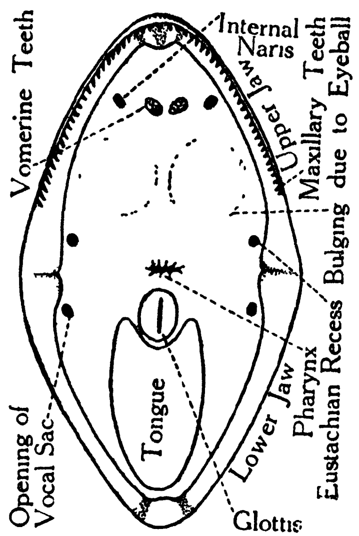

Fig 4 The mouth of the frog, wide open

The floor of the mouth is soft and fleshy and is bordered by the **lower jaw.** The tip of the lower jaw fits nicely into a depression on the **upper jaw,** and when the mouth is closed the opening is perfectly airtight

Practical work

11. Dissection of the Alimentary Canal.—(Fig. 5) Open the frog as directed in Sect. 8. Note that a seeker passed into the throat reaches the **stomach,** showing thereby that the mouth cavity is continuous with the alimentary canal, and indeed is part of it It also shows that the stomach is hollow inside This is true of the entire length of the canal The **oesophagus,** a wide tube, connects the mouth with the stomach The stomach forms a U-shaped bend with the next part of the canal called the **duodenum.** Lying in the bend of the U is a whitish irregularly lobed structure seen to advantage when the U is turned forwards

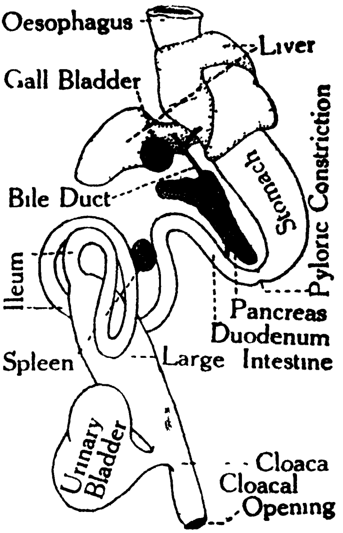

Fig 5 The alimentary canal of the frog, excluding the buccal cavity

Unravel the whole length of the alimentary canal by tearing the mesentery, taking care to preserve the U-shaped bend intact. Remove the liver from where it is attached dorsally, without, however, cutting its connection with the alimentary canal. The posteriormost portion of the canal will be seen to be hidden under the pelvic girdle. In order to see this portion to advantage, split the pelvic girdle by means of a strong, sharp scalpel cutting exactly in the median line and taking care not to injure the urinary bladder

Make out now the **small intestine** or **ileum,** the slender, convoluted portion following the duodenum , the **large intestine** or **rectum,** wider and darker in colour and the **cloaca** or the portion which was covered by the pelvic girdle and into which the **urinary bladder** opens Note that the alimentary canal is several times as long as the body.

12. The Digestive Glands.—The larger digestive glands are the liver and the pancreas Make out the three lobes of the **liver,** two on the left and one on the right A small round greenish sac between the right and left lobes is the **gall-bladder.** A slender duct formed by the confluence of tributaries arising from the lobes of the liver and giving a branch to the gall-bladder is the **bile-duct.** It enters the **pancreas,** an irregularly lobed structure in the U-shaped bend formed by the stomach and the duodenum. The bile-duct after receiving several branches from the pancreas issues out of it as the **common duct** and opens into the duodenum

Practical work

13. The Opening of the Common Duct.—Slit open the duodenum opposite the point where the common duct joins it for about an inch in length. Note the contents—half-digested food—and wash clean. Pin down the edges of the cut to the board. Now, gently squeeze the gall-bladder Note the bile flowing into the duodenum through the common duct Notice the irregular folds of the lining of the duodenum.

(3) Make a diagrammatic sketch of the alimentary system incorporating all the parts seen under Sect 11 and 12

Practical work

14. The Lumen of the Canal.—By means of a pair of fine scissors slit open the entire length of the alimentary canal before and behind the incision already made in the duodenum Note and record the contents of the stomach and other parts of the tube Wash out the contents under the tap Note the folds of **mucous membrane** in the stomach, duodenum, small intestine and rectum and record whether they are transverse, longitudinal or irregular.

Which part of the alimentary canal has the widest lumen, and which the narrowest?

15. The Walls of the Canal.—The thickness of the various parts of the canal varies widely Thus, it will be seen that the stomach has the thickest, and the rectum the thinnest wall. The outermost layer of the tube is the **peritoneum** (See Fig 24), the innermost forms the **mucous membrane** and between the two are layers of **muscles** and **connective tissue.**

16. The Pylorus and the Anus.—These mark the beginning and the end of the intestine, and are characterised by the presence of **sphincter muscles.** In other words the ring-like muscles at these regions are well developed and normally keep the passages closed. The pylorus is seen as a constriction (the **pyloric constriction**) between the stomach and the duodenum, while the anus is a similar constriction marking the terminal portion of the rectum. The passing of food from the stomach to the intestine and the casting out of faecal matter from the rectum are controlled by the respective sphincters.

17. The Alimentary Canal is a Part of the Outer World. (Fig. 6) The alimentary canal has been seen to be much longer than the body itself and consequently convoluted. It is continuous with the skin at the edge of the mouth and the cloacal opening Thus the canal itself is continuous with the outer world through these two openings. Study Fig 6 to understand this better The outer tube corresponds to the bodywall of the frog and the inner tube to the alimentary canal The latter opens to the outside at the mouth and at the cloacal opening, and consequently the space between them is just a part of the outside world with which it is continuous If food is taken at one end, digested in the lumen of the canal and the indigestible part (faeces) cast out at the other end, it is clear that the food never enters the body of the animal as such. The digested food has to pass through the wall of the alimentary canal and thence into other parts of the body before it can be said in a strict sense that the food has been taken *into the body.*

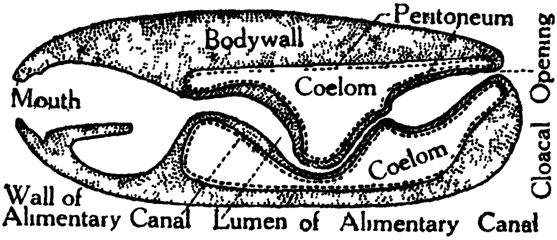

Fig 6 A diagram to show the relation of the alimentary canal of the frog to the outside world

The space between the outer and the inner tubes corresponds to the body cavity or coelom.

18. The Food of the Frog.—The frog's food is quite varied, though it is entirely carnivorous All kinds of insects, centipeds, earthworms and other small land animals make wholesome food for the frog Small fish and tadpoles are also eaten In captivity, the larger frogs may devour the smaller ones. Frogs can eat animals amazingly large for their own size, and they are known even to swallow small snakes Frogs are voracious creatures and stuff themselves full when prey is to be had Only live prey is eaten

Food catching is very peculiar The tongue is hinged at the anterior end of the floor of the mouth and can be suddenly flicked out so as to strike an insect or other small prey On account of the stickiness of the tongue the prey adheres to it and is flicked back into the mouth with equal suddenness. Larger prey are actually caught in the jaws, and the recurved, pointed teeth prevent the escape of the struggling animal. The prey, large or small, is swallowed whole

19. Digestion* and Absorption.—In the course of the passage of the food through the alimentary canal, it comes into contact with various digestive juices secreted by the digestive glands. The lining of the stomach secretes the **gastric juice,** the liver secretes the **bile** and the pancreas secretes the **pancreatic juice.** The lining of the intestine also secretes certain digestive juices These juices have the power of converting the food into a solution in which form alone can food permeate through the wall of the alimentary canal into the rest of the body. Digestion is the conversion of an insoluble food substance into a soluble, and therefore permeable, form Absorption is the diffusion of the digested food into the interior of the body

20. Peristalsis and Defaecation.—The passage of the food along the alimentary canal is effected by a wave of contraction of the circular muscle layer of the wall of the canal Such a wave-like contraction of the gut is known as peristalsis The swallowing of food, its passage along the alimentary canal and defaecation are effected by peristalsis under the control of the nervous system

REVISION QUESTIONS

11. Enumerate and describe the organs of the abdominal cavity Say which of them are single and which paired

12 What is the difference between peritoneum and mesentery ?

13 Define the term coelom Does the coelom contain anything ?

14 What function do you assign to each of the organs you have seen in the present dissection ?

15. Study Fig 3 closely and find out if any organ is included within the true limits of the coelom

16 What is the function of the coelom ? How is friction between the various abdominal organs prevented ?

17 In the sketch of the alimentary canal, mark the pyloric constriction

18 Describe the buccal cavity of the frog

19 What is the difference between the 'lower jaw' and the 'floor of the mouth'?

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* For a fuller account of Digestion, see Sect 369 and 370

20. How does the tongue of a frog differ from that of man? Is it an organ of taste in the case of the frog?

21 Describe the position, shape and arrangement of the teeth of the frog Are they useful for chewing? If not, what is their use?

22 What is the advantage of a long alimentary canal? What purpose is served by the folds inside the various parts of the canal?

23 How is the passage of food from the pharynx downwards effected? Does food ever pass from the stomach back into the mouth?

24 Name the glands you have come across in your dissections What are glands?

25 Does the alimentary canal show any movements? If so, what purpose is served by them? How do these movements differ from those of other parts of the body, e g , the limbs?

26 What does the food of the frog consist of?

27 Plant-food consists of substances in solution which the roots absorb from the soil Is there any essential difference between plants and animals in the matter of absorption of food?

CHAPTER 3

THE RESPIRATORY AND VOCAL SYSTEMS

Material for Study A frog with the abdomen opened, lungs inflated and hardened for at least 24 hours in 10 per cent formaline, a few live frogs under bell jars

21. Dissection of the Respiratory and Vocal Organs.—

(Fig 7) The respiratory organs are the nostrils, buccal cavity, larynx and lungs.

Practical work

Remove the adjoining structures sufficiently to see the bases of the lungs clearly Note the **laryngo-tracheal chamber** at the confluence of the two lungs Cut the floor of the mouth beginning at the tip of the lower jaw, along the median line, until the glottis is reached Note the cartilaginous **hyoid** in the floor of the mouth Pass a seeker into the glottis till it pushes against the inner side of one lung Repeat for the other lung The seeker passes through the laryngo-tracheal chamber or voice box. Split the voice box into two by a thin sharp scalpel passed through the glottis, along the ventral wall, pin the halves apart Note that the walls of the voice box are strengthened by cartilage Observe the passages to the two lungs and the **vocal cords** inside the voice box Carefully note the position and attachment of the cords, their thick free edges, and how when the two halves are pressed together they almost touch each other. Note also the muscles of the voice box.

Chop off a portion of the wall of the lung that has been hardened in formaline. Note the large pulmonary space, and the highly folded interior giving roughly the appearance of a honey comb Blood vessels, (the pulmonary vein and artery), may be seen running on the surface of the lung, and giving off branches which spread all over the lung tissue A layer of peritoneum, the **pleural membrane,** covers the lungs. The blood vessels run under this membrane

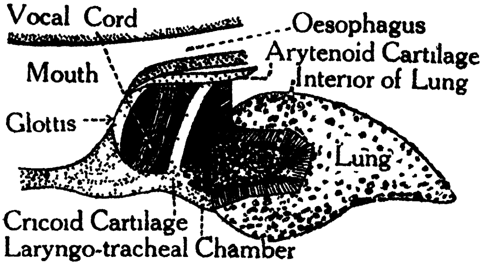

Fig 7 A median longitudinal (sagittal) section through the deeper part of the buccal cavity and the laryngo-tracheal chamber of the frog; the right lung is shown with a portion of its wall removed to show the interior

(4) Sketch your dissection

22. Respiratory Movements.—*(Each batch of three or four students should be provided with a live frog under a bell jar)* You have already noted that three parts of the body show movements concerned with respiration, viz., the external nares, the floor of the mouth and the flanks These may be observed again and recorded below —

MOVEMENT	INCIDENCE 5 MINUTES	ORDER OF INCIDENCE
1. Oscillatory movement of throat		
2. Sharp upward movement of throat		
3. Twitching of nostrils		
4 Falling and heaving of flanks		
5. Opening of glottis	(cannot be seen externally)	

23. The Mechanism of Respiration.—(Fig. 8) It has been seen that the glottis is normally closed For, the inflated lungs did not collapse when the blow pipe (Sect 8) was drawn away. In life, the glottis opens at intervals only, and then too by muscular action, in order to let the air in the lungs escape and fresh air enter And this coincides with movement 4 in the table above The buccal cavity is thus open to the outside alone, and that too through the nostrils, the mouth being closed except when food is being taken When the floor of the mouth rises and falls air is expelled and taken in respectively through the nostrils It has been noted that these oscillatory movements take place all the time The result is that the air in the mouth is being continually renewed from the atmosphere The walls of the buccal cavity being highly vascular, exchange of gases (oxygen and carbon dioxide) takes place between the air in the buccal cavity and the blood-vessels of the buccal lining. This constitutes **buccal respiration.**

The falling and heaving of the flanks respectively mark the contraction and expansion of the lungs, which are normally full of air. At intervals coinciding with the closure of the nostrils, the glottis opens and the air in the lungs is pressed out into the buccal cavity by the elastic recoil of the lungs assisted by the contraction of the flanks Thence part of the expired air escapes to the outside with the air already in the buccal cavity This constitutes an expiratory act or **expiration.** Fresh air is now drawn into the buccal cavity, the nostrils close, and the strong sharp upward movement of the throat forces the air in the buccal cavity into the lungs through the glottis which now closes again and imprisons the air in the lungs This constitutes the inspiratory act or **inspiration.** Exchange of gases takes place between the imprisoned air and the blood in the

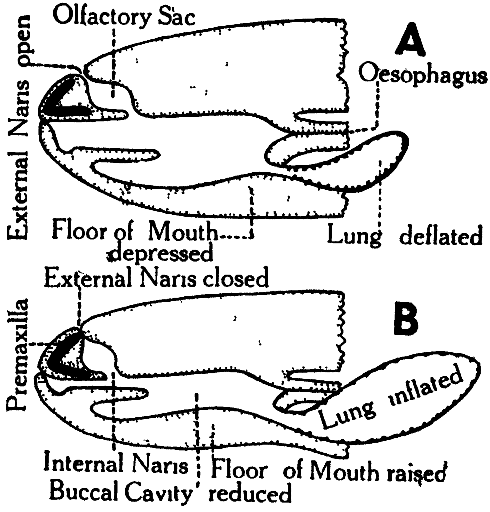

Fig 8 Diagrams illustrating the respiratory movements of the frog (Modified from Parker and Parker)

walls of the lungs, which present a very large area to the air The air is retained in the lungs for a considerable time before expiration takes place again, and during this time its carbon dioxide content is increased Thus lung or **pulmonary respiration** takes place. A little reflection will show why movements 2, 3, 4 and 5 take place almost simultaneously, for they are all concerned with pulmonary respiration The order of events in pulmonary respiration may now be given

- i. Expiration
  - 1 Glottis opens
  - 2 Lungs and flanks contract—Air expelled into buccal cavity.
  - 3 Throat rises—Air from buccal cavity expelled through nostrils.
- ii Inspiration
  - 4 Throat falls—Fresh air enters the buccal cavity.
  - 5 Nostrils close.
  - 6 Throat rises sharply—Air forced through glottis into lungs
  - 7 Lungs and flanks dilate
  - 8 Glottis closes—Air imprisoned in lung
- iii. Long interval of respiratory exchange
- iv Expiration 1. Glottis opens

The closure of the nostrils is effected by the tip of the lower jaw pressing against the premaxillae (Fig 8, B) or bones at the anterior end of the upper jaw The movements of the throat are caused by the contraction of muscles of the floor of the mouth attached to the hyoid and to the lower jaw bones

24. Cutaneous Respiration.—Besides the buccal cavity and the lungs, the moist skin of the frog also is an important respiratory organ. The skin is richly supplied with blood-vessels, and therefore respiratory exchange can take place between the skin and the atmosphere During periods of excessive warmth, drought or cold, the frog buries itself in the ground and remains in a torpid condition. Respiratory movements stop and the animal subsists almost entirely on cutaneous respiration Also when under water and direct breathing from the air is out of the question, the frog respires only through the skin In normal conditions cutaneous respiration supplements pulmonary and buccal respiration. A frog can live for several days depending entirely on cutaneous respiration, when artificially prevented from breathing through the nostrils

25. The Essence of Respiration.—The complex mechanism of respiration as we have seen it in the frog is but a means of bringing the atmospheric air into relation with the internal surface of the lungs and the buccal cavity In cutaneous respiration, no such mechanism is necessary, Any surface which is vascular, that is, supplied with blood capillaries, and which is exposed to the air, atmospheric or dissolved in water, can serve as a respiratory organ. The purpose of special respiratory organs like the lungs is to increase the area of the surface thus presented to the air When the surface is an internal one as in the case of the lungs of the frog and higher animals, it becomes necessary to have a *mechanical* devise for the constant renewal of the respiratory air Hence the mechanism of respiration by which the in-take (inspiration) and the out-flow (expiration) of air are effected It will thus be seen that the mechanism of respiration, though very necessary, is quite subservient to the real internal respiratory processes

The internal respiratory process include (1) the physical processes of exchange of gases between the air and the respiratory surface by diffusion, and (2) the chemical processes of (a) combination of the oxygen with the red pigment (haemoglobin) of the blood to form oxy-haemoglobin, (b) the decomposition of oxy-haemoglobin to form haemoglobin and oxygen and (c) the oxidation of the living protoplasm of the tissues of the body by this liberated oxygen, evolving carbon dioxide, water and other products of tissue decomposition as well as energy

In the *physical* process of diffusion, the oxygen of the air enters the blood, the two being separated only by the thin lining of the lungs and of the capillaries The blood reaching the lung capillaries is poor in oxygen, but rich in carbon dioxide, compared to the atmospheric oxygen, and consequently oxygen diffuses into the blood capillaries, while carbon dioxide diffuses into the air inside the lungs.

The first part of the *chemical* process takes place in the lung capillaries The oxygen as soon as it reaches the capillaries, unites chemically with the haemoglobin forming an unstable compound called oxy-haemoglobin This change is marked by the change in colour of the blood from bluish to bright red The second and third part of the chemical process take place, not in the lungs, but in the tissues of the body, whither the oxygenated blood from the lungs is carried by the blood vessels· As the blood traverses the capillaries of the body, the oxy-haemoglobin is split into haemoglobin and oxygen. The latter diffuses through the thin walls of the capillaries to the cells whose protoplasm is oxidised by it, splitting up the complex molecule of protoplasm into simpler ones such as water, carbon dioxide, and a host of others, some of which are useful for the body, while others like urea and uric acid are harmful and are excreted from the body All these products of the decomposition of proto plasm are passed back into the blood, and the carbon dioxide and part of the water diffuse into the atmospheric air in contact with the respiratory surfaces.

This last phase of respiration, viz., the process of oxidation of the living molecules, may be distinguished from the other phases as **internal respiration** or tissue respiration, and is the most essential part of the entire respiratory phenomenon

26. The Production of Voice.—The vocal cords (Fig 7) are placed in the path of the expired air where it is narrowest, and consequently the current strongest They are set in vibration by the air passing between them The variation in the pitch are caused by altering the tension of the cords by the action of the laryngeal muscles The vocal apparatus of the male frog is better developed than that of the female Often the males also possess a pair of **vocal sacs,** which are skin-pouches opening into the mouth They can be inflated with air while croaking Their function is to resonate the sound produced by the vocal cords, not unlike the sound box of a musical instrument (See Sect 5)

REVISION QUESTIONS

28 What is the principle of a suction pump? How does it differ from a force pump? How is the air drawn into the buccal cavity and how is it taken into the lungs?

29 How is breathing carried on in man?

30 Does respiration take place in animals that have no breathing organs? if so, how?

31 What part is played by the blood in respiration? Some animals have no blood Is respiration possible in them?

32 Where does venous blood become arterial and arterial blood become venous? What is the difference between arterial and venous blood?

33 What would happen if the nostrils of a frog are plugged with wax, if the mouth is forcibly kept open, if the frog is kept in a dry atmosphere?

34 What would happen if the abdominal wall of a frog were pierced in the region of the lungs and also if one of the lungs itself were pierced?

CHAPTER 4

THE BLOOD VASCULAR SYSTEM—THE HEART—DISSECTION OF THE VEINS

Material for Study A just chloroformed frog for each student

27. Blood and Lymph Systems.—The vascular system consists of two closely allied systems, the blood vascular system and the lymph vascular system The former is quite conspicious since it contains red blood running in vessels which can be easily seen and dissected, while the latter is made out only with difficulty, since it contains a colourless fluid called lymph flowing in the big spaces of the body and in ill-defined vessels and passages often lacking a limiting wall We shall examine the blood vascular system first

28. Examination of the Heart.—Open the frog as usual, out of water, taking care not to injure the abdominal vein (See Sect 8) The **heart** has already been noted It is invested in a double membrane, the **pericardium,** the outer layer being separated from the inner by a clear **pericardial fluid.** Pinch the outer layer of pericardium with a pair of forceps and make a small incision in it by a pair of scissors Note how the pericardial fluid oozes out What is the use of the pericardial fluid? Remove the entire pleural or outer layer of pericardium as clean from the base as possible The outlines of the heart are now seen to advantage The conical posterior end of the heart is the **ventricle,** and the rounded anterior part is the auricular portion consisting of a **right auricle** and a **left auricle.** Push the ventricle forward and note the thin-walled dark coloured part, the **sinus venosus,** which lies dorsal to the ventricle Finally, make out the **truncus arteriosus,** a short cylindrical whitish tube lying on top of (ventral to) the auricles.

Practical work

Observe the **beat of the heart.** Where does it start and in what order does the contraction proceed? How do you account for the change of colour of the ventricle when it contracts? Why is it that the colour of the various parts of the heart is not uniform throughout. What happens to the blood inside the heart when the heart beats? Explain why the frog's heart continues to beat after chloroforming.

(5) Sketch the ventral view of the heart and mark all the parts seen.

29. The Veins.—The veins are blood vessels which bring the blood from the various parts of the body to the heart These are a pair of **anterior vena cavae** returning blood from the head, fore-limbs, shoulder and the skin, in other words from the anterior region of the body, a single **posterior vena cava** returning blood from the trunk, hind limbs and the internal viscera, and a pair of **pulmonary veins** returning blood from the lungs We shall consider each of these separately (See Fig 9)

(a) **The Anterior Vena Cavae.**— These can be seen joining the anterior corners of the sinus venosus They are wide, thin-walled, dark tubes continuous with the sinus venosus

Practical work

Great care should be taken in dissecting the veins as they may be easily cut or punctured and the blood flow out emptying the veins and making them difficult to see or dissect Trace the right anterior vena cava outwards from the sinus venosus until you reach its three tributaries. These are (1) the **external jugular,** anteriormost and receiving the blood from the tongue by a small **lingual** vein and from the lower jaw by a **mandibular** vein; (2) the **innominate** receiving blood from the interior of the skull by an **internal jugular** and from the back of the arm and

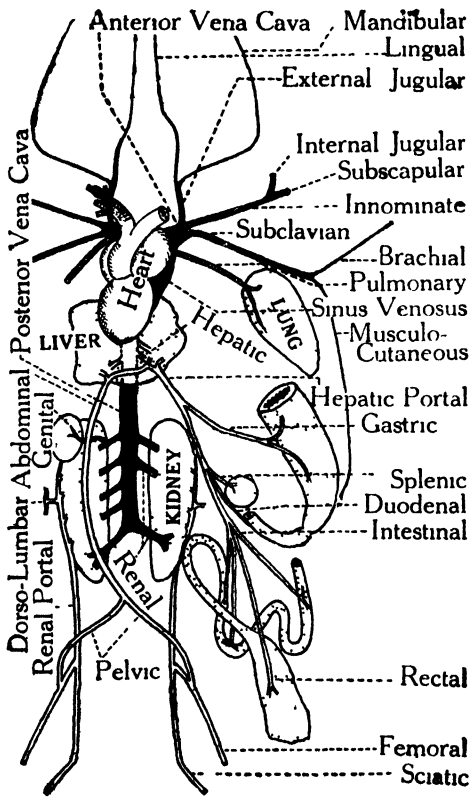

Fig 9 The venous system of the frog from the ventral side Vessels carrying deoxygenated blood, dark, oxygenated, striped, portal veins, unshaded

shoulder by a **subscapular,** (3) the **subclavian,** posteriormost and largest of the three, receiving blood from the arm by a **brachial** vein and from the skin and muscles of the back of the body by a **musculo-cutaneous** vein.

Note that most veins are named after the part of the body from which they return the blood

The left anterior vena cava is symmetrical with the right and has corresponding branches

The **thyroid gland,** a small round reddish body on the external jugular vein, should be noted It is one of the several ductless glands of the body (See Sect 417)

Press one of the longer veins you have dessected between the fingers so as to drive away the blood from that portion Note from which direction the blood flows to fill up the gap when the pressure is removed This shows clearly that the blood in the veins flows towards the heart.

(6) Sketch and label the parts of the anterior vena cava

(b) **The Posterior Vena Cava.**—This enters the sinus at its posterior end Trace it down the body and make out the following tributaries — (1) the **hepatic veins,** paired, short, wide veins bringing blood from the lobes of the liver, (2) the **renal veins,** several pairs of small veins from the kidneys joining the vena cava behind, and (3) the **genital** veins, bringing blood from the ovaries or testes as the case may be

The veins from the hind limbs and the alimentary canal do not reach the posterior vena cava directly, because these veins enter the kidneys and the liver respectively, and their blood has to pass from these organs into the renal or hepatic veins and thence into the posterior vena cava Veins that are thus intercepted on their way to the heart by other organs are called **portal veins.** Those that are intercepted by the kidney are the renal portal and those intercepted by the liver are the hepatic portal veins

(c) **The Renal Portal Veins.**—These are a pair of veins joining the kidneys along their outer sides.

Remove the coelomic epithelium from over the kidneys and note these veins Trace them on to their source towards the hind limbs. Split the pelvis as directed in Sect 11 and trace the veins on to the thighs Note (1) the **femoral** vein running along the outer margin of each hip bone or femur, and (2) the **sciatic** vein or hip vein along its inner margin These two veins unite to form the **renal portal.** From the back of the body blood is returned by a pair of (3) **dorso-lumbar** veins, each of which enters the corresponding renal portal at about the middle of the length of the kidney The femoral vein on each side gives off a **pelvic** vein which passes ventralwards and unites with its fellow to form the **anterior abdominal** vein.

(d) **The Hepatic Portal Vein.**—This is a single median vein. It originates in a number of small veins from the various parts of the alimentary canal, viz , the **gastric, duodenal, intestinal** and **rectal** and from the spleen, viz , **splenic.** Trace the hepatic portal and its tributaries after spreading out the length of the alimentary canal These veins lie in the broad mesentery between the two folds of peritoneum The hepatic portal itself enters the left lobe of the liver at its posterior margin Before entering the liver it gives off a branch which joins the anterior abdominal vein near the liver.

(e) **The Anterior Abdominal Vein.**—This is formed by the confluence of the paired **pelvic** veins, and lies in the median line immediately inside the ventral bodywall At its anterior end it joins the liver, and immediately before this, is joined by a branch of the hepatic portal

(f) **The Pulmonary Veins.**—From each lung the blood is returned to the left auricle by a pulmonary vein The two pulmonary veins unite near the auricle and open by a common opening What is the nature of the blood in the pulmonary veins, remembering that the lungs are respiratory organs? Trace one of the pulmonary veins to its end on the dorsal side of the left auricle

(7) Sketch the posterior vena cava, the three portal veins (renal portal, hepatic portal and anterior abdominal) and the pulmonary vein, all in one figure.

CHAPTER 5

THE BLOOD VASCULAR SYSTEM (Contd)—DISSECTION OF THE ARTERIES

Material for Study A just chloroformed frog for each student

30. The Arteries.—The arteries are blood vessels which bring the blood from the heart to the various parts of the body. There are three pairs of main arteries which leave the truncus arteriosus. (See Fig. 10).

Practical work

Clean the truncus arteriosus and note that it divides into two large branches, right and left. From each of these arise the arterial trunks.—(1) the carotid arch, (2) the systemic arch and (3) the pulmo-cutaneous arch. Put a roll of paper into the gullet of the frog so as to distend it This would stretch the arteries slightly and make them more easy to dissect Note that the arteries have thicker walls, and consequently they are firmer than the veins and easier to dissect Dissect the arteries either on the right or on the left. ✓

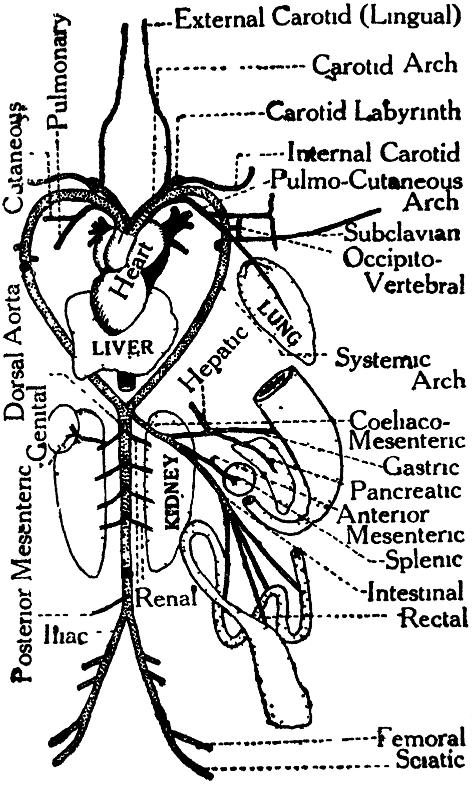

Fig 10 The arterial system of the frog Vessel carrying deoxygenated blood, dark , oxygenated striped , mixed dotted

(a) **The Pulmo-cutaneous Arch.**—Trace the pulmo-cutaneous arch, the third and the smallest of the three arches It soon divides into a very small **cutaneous** artery and a **pulmonary** artery Trace the former into the skin and the latter into the lung

(b) **The Systemic Arch.**—This is the second arch, and the largest of the three, so called because it supplies blood to the various *systems* of the trunk Trace the systemic on one side, looping round the gullet dorsalwards. Note the four small branches given off from the loop, viz , **laryngeal, oesophagial, occipito-vertebal** and **subclavian.** As it reaches the dorsal side of the gullet, it is joined by the systemic of the other side, and the two together form the **dorsal aorta** which lies in the sub-vertebra

lymph space Push aside the internal organs in order to dissect this artery further Trace the **brachial** artery to the arm From where the two systemics unite in the dorsal aorta is given off a ventral artery, the **coeliaco-mesenteric** artery, which, as the name implies, lies in the mesentery and gives branches to the various coelomic organs Trace the coeliaco mesenteric into its branches, viz, the **hepatic, gastric, pancreatic, splenic, intestinal** and **rectal** arteries, until the respective organs are reached The dorsal aorta gives off paired **renal** arteries to the two kidneys, and also **genital** arteries to the gonads Further back, it divides into two **iliac** arteries, one in each hind-limb Each iliac divides into a **femoral** and a **sciatic** artery

(c) **The Carotid Arch.**—This is the anteriormost of the three, dividing after a short length into two (1) the **external carotid** or **lingual,** supplying the tongue with blood, and (2) the **internal carotid** which supplies the brain after looping dorsalwards round the gullet The beginning of this branch is marked by a swelling called the **carotid labyrinth.** This labyrinth is a small spongy mass obstructing the free flow of blood in the internal carotid

The arteries are named after the part of the body to which they carry blood

(8) Sketch the arterial system

31. The Difference between Arteries and Veins.—Veins carry the blood towards the heart, while arteries carry it away from the heart Veins have thin walls which collapse when they are emptied of blood, but arteries have thick walls which do not collapse even when empty (After death, veins are full of blood while the arteries are empty) Valves are placed in some of the larger veins which allow the blood to flow only towards the heart, while in the arteries no valves are present except where they leave the ventricle of the heart (See also Sect 67)

32. The Capillaries.—Wrap a live frog in a wet piece of rag leaving one of the hind limbs and the head free Make a hole one inch in diameter in a piece of thick card board 6″ × 4″. Stretch the web of the frog's foot over the hole and pin it down by the edges to the cardboard Make a pedestal of books or other objects as high as the stage of a microscope, and

Practical work

place the cardboard with the frog on top of it in such a manner that the hole with the web rests on the stage of the microscope in the path of the light

The flow of blood in the various blood vessels can now be seen under the microscope Follow up the direction of the current in the larger vessels It will be noted that the blood flows in opposite directions in vessels lying parallel to each other. Determine which are arteries and which veins, remembering that under the microscope the image, and hence the direction of the current, are reversed. Follow an artery to its smallest branches These are called the **capillaries.** The red blood corpuscles can be seen moving very slowly and in one file in the capillaries, whereas in the arteries they move more quickly and several abreast Follow up the capillaries till you see them unite and form larger vessels which are the smallest veins You will again note that the current in them is stronger and several corpuscles move abreast The direction of the current also is changed [*] Note that the capillaries form a net work with islets of cells occupying the meshes of the net

(9) Sketch the capillaries

In this experiment, the flow of blood in the capillaries can be actually seen in the microscope on account of the thinness of the web. Presumably what is true of the web is true of other parts of the body. The blood from the larger arteries pass into the smaller ones and from these into the capillaries From the capillaries it flows into the smaller veins and from them into the larger ones, which as we have seen, empty their blood into the heart From the heart the blood flows into the arteries Thus the blood *circulates* in the body

CHAPTER 6

THE BLOOD VASCULAR SYSTEM (Contd)—DISSECTION OF THE HEART—CIRCULATION OF BLOOD—THE BLOOD

Material for Study The heart of a large frog treated as follows,—Kill and open the frog, dissect the roots of the arteries and the mouths of the venis. Preserve the frog in 10 per cent formaline for two days in order to harden the heart Then remove the heart from the body by cutting the blood vessels at the points indicated below anterior venacavæ, where they receive their tributaries, posterior vena cava where it leaves the liver, carotid arches, beyond the level of the carotid labyrinth, and the systemic arches before the subclavians branch off The lungs may be removed with the heart, hanging by the pulmonary arteries and veins

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[*] The circulation of blood is very clearly and easily seen in the tail of a living tadpole examined under the microscope in a watch-glass

33. Dissection of the Heart.—(Fig 11) Lay the heart dorsal side up, pin down the ends of the various vessels and the lungs Dissect under water Clean the dorsal side of the heart.

Practical work

(10) Sketch the dorsal and lateral views of the heart

Cut one of the pulmonary veins close and pass a bristle into the left auricle through the cut Remove the dorsal wall of the sinus venosus and pass a thin roll of paper into the sinu auricular opening leading from the sinus to the right auricle

Now, pin the heart ventral side up

Snip off the ventral wall of the two auricles leaving the portion covered by the truncus arteriosus untouched. Wash out the blood clots in running water using a soft brush Note (1) the **cavities of the auricles** with strands of muscle crossing from wall to wall, (2) the **interauricular septum** or partition between the two auricles, (3) the **sinu-auricular opening** marked by the roll of paper projecting into the right auricle, (4) the **sinu-auricular valves** in the form of two little flaps of membrane in front and behind the roll and (5) the **opening of the pulmonary vein** into the left auricle marked by the bristle

Search for the (6) **auriculo-ventricular openings** in the posterior wall of the auricles, and pass two thin rolls of paper, one from each auricle to the ventricle Carefully cut away the ventral wall of the ventricle starting from the base of the truncus arteriosus and passing to the apex Note the thick walls of the ventricle as compared with the walls of the auricles, (7) the column like **trabeculæ** projecting into (8) the **cavity of the ventricle,** (9) the **auriculo-ventricular openings**

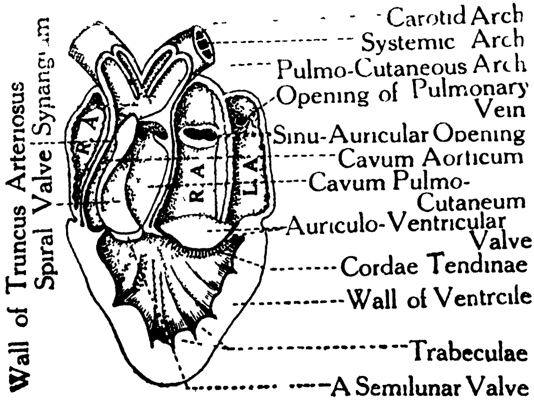

Fig 11 The heart of the frog dissected from the ventral side to show the internal structure. The ventral wall of the ventricle, auricles and truncus arteriosus are removed (Modified from Howes)

marked by the rolls of paper, (10) the **auriculo-ventricular valves** arising from the margin of the openings and projecting into the ventricle in the form of two thin flaps and (11) the **cordæ tendinæ** or small cords of tendon by means of which the flaps of the valves are held to the interior of the ventricles

Pass a thin roll of paper from the ventricle into the truncus arteriosus Make an incision into the wall of the latter along its left, open the cut and remove the upper (ventral) wall without injuring the internal structures Note (12) the **opening from the ventricle** marked by the roll of paper, (13) the three **semilunar valves** guarding the opening and having their free ends directed towards the truncus, (14) the **spiral valve** attached longitudinally to the dorsal wall and forming a thick spiral flap in the form of an open S, (15) the **pylangium** or the chamber in which the spiral valve lies, (16) the **synangium** or the chamber from which the arteries branch out, (17) the **semilunar valves** separating the pylangium from the synangium, (18) the **cavum pulmo-cutaneum** on the left of the spiral valve, the opening into (19) the **pulmo-cutaneous arches** in the dorsal wall of the truncus at the level of the anterior end of the spiral valve, (20) the **valve** which guards this opening, and (21) the **cavum aorticum** on the right of the spiral valve passing anteriorly into the synangium and thence into the openings of the carotid and systemic arches

Pass bristles into the pulmo cutaneous, the systemic and the carotid openings, and note that they find their exit at the cut ends of the corresponding arches, but that in the case of the carotid, the carotid labyrinth offers resistance to the passage of the bristle.

(11) Sketch the dissection of the heart from the ventral side

34. Circulation of Blood in the Heart.—(Fig 12) The dissection of the heart has shown that it is a blood vessel with thick walls constricted into chambers and having valves between them It is bent in the form of an S as the figure of the side view shows. In the earlier stages of development, indeed, the heart is a simple straight tube in which the blood flows from the sinus end to the truncus-end, bending in the course of further development into its characteristic shape and becoming separated into the various chambers by the formation of constrictions The bending results in the auricular portion, originally behind the ventricle, being placed in front of it in the adult condition. The modifications that come about in the heart serve two main purposes. the pumping of the blood as if from a central station

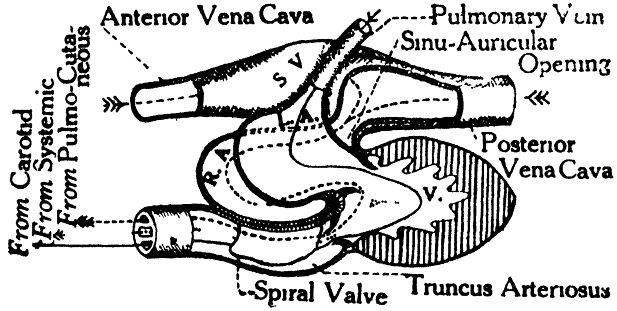

Fig. 12 The heart of the frog dissected from the left side The auricles and ventricle are fully exposed, the sinus venosus and truncus arteriosus, partly The sinu-auricular opening is shifted a little backwards for clearness The arrows indicate the direction of the currents of blood The broken line indicates the course of deoxygenated blood, the dotted line, of mixed blood and the unbroken line of oxygenated blood
L A, left auricle, R A, right auricle, S V, sinus venosus, V, ventricle

by the contraction of the strong muscular walls and the regulating of the current produced in one unchanging direction by the peculiar disposition of the valves

The anterior and posterior vena cavæ return the deoxygenated blood from the various parts of the body except the lungs into the sinus venosus The pulmonary veins bring the oxygenated blood from the lungs into the left auricle The first part of the heart which contracts is the sinus venosus and the blood in it, being subjected to pressure, is sent into the right auricle through the sinu auricular opening The wave of contraction now passes on to the auricles, both of which contract simultaneously and press upon the blood contained in them The sinu auricular valves are pushed by the blood towards the sinus, and the two flaps meeting each other close the sinu-auricular passage The ventricle is at this moment in diastole (that is, relaxing) and the blood in the two auricles, deoxygenated and oxygenated respectively, finds easy access to it through the auriculo ventricular passage and fills the ventricle In doing so the deoxygenated blood from the right auricle occupies the right half of the ventricle including

In the fishes there are no lungs and therefore there is no pulmonary circulation, but only the circulation through the various systems of the body or systemic circulation. In animals like the frog where both exist, and consequently the blood has to pass through the heart twice in the course of one complete circuit, we speak of **double circulation.**

36. The Blood under the Microscope.—(Fig 14) Procure a few clean dry glass slides and coverslips Open a freshly killed frog and expose the heart Pierce one of the veins or the heart itself and by means of a clean glass rod place a tiny drop of blood at the centre of the slide Touch the drop with the edge of the coverslip held between the fingers, and with the help of a mounted needle lower the slip on to the slide so as to spread out the drop in a thin even film The film should be made quickly as otherwise the blood will clot and would not spread out If the first attempt is not successful make a second Examine under the microscope

Practical work

If the film has been properly made, you will make out the following under the low power of the microscope The whole field of the microscope will be seen to be strewn with small oval bodies These are the **red blood corpuscles,** of a light yellow colour and having a small oval **nucleus** seen as a clear area of a bluish tinge Among the red blood corpuscles are found here and there the **white blood corpuscles.** They are smaller in size and fewer than the red Turn on the high power Note that the red corpuscles have a clear protoplasm (the substance of which the corpuscles is made), while the white have a granular protoplasm Observe a white corpuscle closely and sketch its outline at frequent intervals Compare the outlines and note how the corpuscle has been changing its shape all the while In addition to the corpuscles, there is a clear fluid or **plasma** of the blood in which the corpuscles float

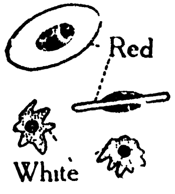

Fig 14 Blood corpuscles of the frog One of the red corpuscles seen edgewise (×550)

(12) Sketch the red and white blood corpuscles

37. The Colour of Blood.—The colour of blood is due to the presence of an iron compound called **haemoglobin** suspended in the protoplasm of the red corpuscles When seen in a very thin layer as in the blood film, it is light yellow, but when seen in a thick layer, as in drawn blood, it is red The plasma is colourless Oxygenated blood is red in colour Its scarlet colour is due to **oxyhaemoglobin** (See Sec 25) Deoxygenated blood, on the other hand, has a bluish tinge, the colour being due to haemoglobin. When exposed to air it absorbs oxygen and turns scarlet.

38. Composition of Blood.—As we have seen above blood contains **corpuscles** and the **plasma** in which they are suspended The corpuscles carry a larger or smaller amount of **oxygen** in chemical union with their haemoglobin The contents of the blood may vary greatly in different parts of the body, and at different times Thus the **absorbed food** which has diffused into the blood through the mucous membrane of the alimentary canal is an important constituent of blood, found more abundantly in the hepatic portal veins after digestion and absorption The absorbed food reaches the heart and is sent to the various parts of the body, so that blood from any part of the body would contain a proportion of absorbed food meant for the feeding of the tissues As the result of oxidation of the tissues, the blood receives **carbon dioxide, water** and **nitrogenous waste matter,** which will therefore be abundant in the venous blood of the systemic circulation Blood also carries various secretions of the ductless glands called **hormones** or **internal secretions.** (See also Sect 393)

39. The Functions of Blood.—We have already noted some of the important functions of blood (1) It is a medium in which the absorbed food is carried to the various parts of the body (2) It carries oxygen to the various parts of the body for the oxidation of the tissues whereby waste products and heat are produced. (3) It carries away the waste products to the various excretory organs which eliminate them from the body Other functions are (4) It takes up the heat that is evolved in oxidation or tissue decomposition and in flowing through the various parts of the body imparts this heat to those parts in which oxidation is slow or which being in contact with the outside water or atmosphere lose their heat more rapidly, thus tending to keep the temperature of the various parts more or less the same at any given time. (5) It supplies the raw materials blood capillaries into the intercellular spaces or lymph capillaries. Thus the lymph bathes the individual cells of the body, enabling them to take from it the absorbed food dissolved in the plasma.

44. Circulation of Lymph.—The lymph that is formed in the intercellular spaces or lymph capillaries passes into the lymph vessels and thence into the lymph spaces of the body The lymph vessels and spaces are in communication with the **lymph hearts.** These are two pairs of thin-walled muscular organs which pulsate regularly and cause the lymph to be pumped into the blood system with which they are in communication The anterior pair of lymph hearts lie one on either side of the spinal column, just behind the transverse process of the third vertebra, and each empties into the corresponding subscapular vein The posterior pair lies at the hind end of the urostyle, one on either side Each opens into the corresponding femoral vein. Thus the lymph ultimately empties into the bood vascular system.

The circulation of lymph is different from the circulation of blood in that the direction of the current in all vessels is from the capillaries towards the hearts only, the lymph reaching the capillaries again by the medium of the blood.

45. Functions of the Lymph.—We have seen in the web of the frog (Sect 32) the little islets of cells occupying the meshes of the capillary network The blood system being a closed system, the needs of the islets cannot be served by the blood directly The plasma, however, exudes out through the thin walls of the capillaries into the intercellular spaces and bathes the individual cells, which are thereby enabled to take the nutriment contained in it (Fig 15) The blood system can be compared to the railway which carries men and things over long distances along certain routes only and the lymph system to the subsidiary, but very essential, motor traffic which carries them to our street doors

The lymph also carries away the products of tissue decomposition from the individual cells to the venous blood, and ultimately through the blood to the organs where they are excreted or used up

Another function of the lymph system is to give rise to the white corpuscles which play a very important role in the defence of the body against disease (See Sect. 39). The white corpuscles are formed by cell division of the tissue of the so-called **lymph-glands** (See Sect.

402), placed at intervals along the course of the lymph vessels. Since the lymph flows into the blood stream, the white corpuscles of the blood are being constantly replenished by the lymph.

REVISION QUESTIONS

56. Trace the course of circulation of the white corpuscles

57 What do you mean by a closed system of vessels? Is the lymph system a closed system?

58. Why are the lymph vessels more difficult to dissect than blood vessels?

CHAPTER 8

DISSECTION OF THE URINO-GENITAL ORGANS—MICROSCOPIC STRUCTURE OF THE KIDNEY—EXCRETION OF URINE—OTHER EXCRETORY ORGANS

Material for Study A killed frog for each student, micro-slide of t s kidney of frog

46. Dissection of the Excretory and Genital Organs.—(Fig. 16) The excretory and genital systems of the Vertebrate animals are structurally related, and it is convenient for that reason to study the two systems in one dissection A consideration of Reproduction will be deferred to Chapter 19

Practical work

Open the frog as usual, cut the alimentary canal in front of the rectum, tear off the portion anterior to the cut from the mesentery and pin it forwards, so that the whole of the body cavity is empty except for the heart and lungs Split the pelvis as directed in section 11, and pin the rectum with the urinary bladder backwards Remove the coelomic epithelium from the dorsal wall of the body cavity Note the following —(1) The **sub-vertebral lymph space** (See Fig 3) in which (2) the **kidneys** and (3) the **blood vessels** lie Carefully note the blood-vessels that enter or leave the kidneys. (4) The **fat-bodies,** yellow tufts of tissue (which float when the dissection is placed in water Why?) serving as a store of nutriment to the frog when food is scarce Remove the fat-bodies close on the right side The gonads, (5) a pair of **testes** in the male, yellow oval bodies placed behind the fat bodies, and attached to the kidney by a double fold of peritoneum called (6) the **mesorchium;** or (7) **ovaries** in the female, a pair of irregular sac-like structures attached to the anterior end of the kidneys by a fold of peritoneum called (8) the **mesovarium.** The size of the gonads in the various frogs will vary according to their age It also depends upon the season of the year. In the breeding season they will be largest, and the ovaries will be seen to be studded all over with small round eggs Remove the right

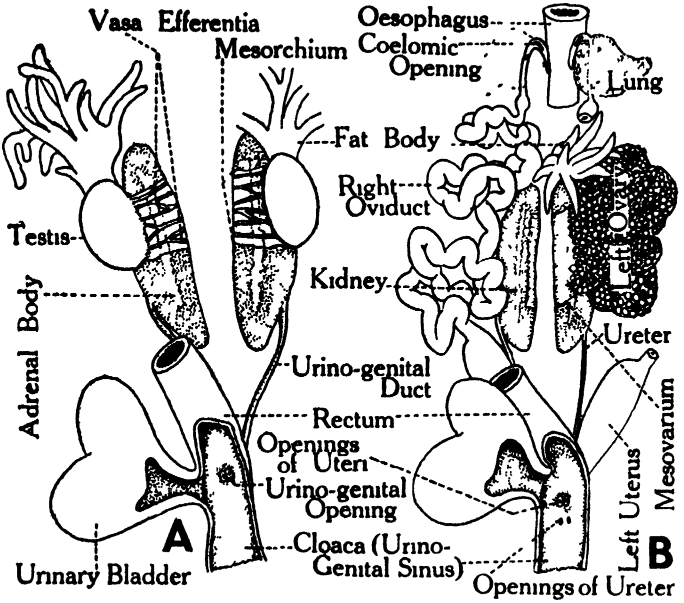

Fig. 16 **A**, male and **B**, female urino-genital organs, dissected from the ventral side The cloaca and the basal portion of the bladder are exposed to show the urinary and genital openings The right ovary and fat body and the left oviduct are entirely removed in B

ovary entire by cutting the mesovarium Cut open the detached ovary and note that it is a hollow sac and see the eggs in various stages of growth (9) The **oviducts** are a pair of highly convoluted, thick-walled ducts running longitudinally along the lateral borders of the body cavity, they are developed in proportion to the size of the ovary Trace one of the ducts along the convolutions to its anterior end on the sides of the root of the lungs where it opens by a funnel-like mouth or **ostium.** Trace it backwards into the ovisac or **uterus,** a dilated chamber in which ripe eggs are retained before laying. Note that the two uteri open into the cloaca each by an opening. Cut off the right oviduct entire, noting (10) the **meso-metrium** or fold of peritoneum by which it is held to the bodywall,

(11) The **adrenal bodies** are yellow patches of tissue on the ventral sides of the kidneys in the form of longitudinal bands (12) The **ureters** are whitish, narrow tubes, one for each kidney, arising from its outer posterior margin Trace the ureters till they enter the cloaca dorsally Note that in the female their openings are behind the point where the oviducts open The posterior end of the ureter in the males dilate to form the **vesicula seminalis** or seminal vesicle. The size of this organ varies in the different species of frogs and according to the season of the year (13) The **urinary bladder** is a pear shaped, thin-walled, bilobed sac opening into the cloaca by a narrow stalk like portion.

Open the cloaca by means of a pair of scissors, beginning at the cloacal aperture and passing forwards along the right or left side Turn over and pin down the cut edge Wash clean in running water Note in the male the paired **urino-genital openings** and the single median **opening of the urinary bladder;** and in the female, note the paired **openings of the uteri,** a little in front of the openings of the ureters Which of these openings are placed on the dorsal side of the cloaca and which on the ventral?

(13) Sketch the urino-genital organs in a full page diagram, showing the arrangement in the male and the female side by side

Cut out one entire kidney from a male frog along with the testis attached to it Pin it down on a board over a piece of black paper pulling the testis on to the inner side of the kidney so as to stretch the mesorchium Between the two folds of peritonium making up the mesorchium, identify about ten fine white ducts, (14) the **vasa efferentia** leading from the testis to the kidney Some of these ducts will be seen to anastomose

(14) Sketch.

47. Relation between Excretory and Genital Organs.— The last dissection shows that there is a close structural relation between the excretory and genital systems, particularly in the male frog The vasa efferentia from the testis pass into the kidney The sperms produced in the testis are consequently conveyed into the kidney. Thence the sperms pass into the ureter which is therefore a spermiduct or **vas deferens** in addition to being a urinary duct or ureter.

In both sexes the cloaca is a **urino-genital sinus,** for into it both the urinary and genital products pass The indigestible refuse from the rectum also is received by it All these products are expelled from it from time to time through the cloacal opening.

Practical work

48. The Minute Structure of the Kidney.—(See Figs 17, 18 and 25, A) Examine under the microscope a stained transverse section of the kidney of the frog. Make out the following under the low power (1) circular, oval and elliptical figures all over the section with paired parallel lines here and there These are the cut ends of convoluted **uriniferous tubules.** Turn on the high power and note that each figure is made up of a number of squarish cells with a deeply stained nucleus in each (2) The **connective tissue** between the tubes (3) Dark round bodies arranged towards the less convex edge of the section (corresponding to the ventral side of the kidney) called the **Malpighian capsules ;** examine one of these under the high power and note the double-walled sac called the **Bowman's capsule,** in which lies a knot of blood capillaries called the **glomerulus.** (4) The **ureter** cut across is seen as a fairly large circle (this marks the outer edge of the kidney) (5) The **renal portal vein** dorsal to the ureter and having thinner walls than it (6) The **Bidder's canal** seen as a fine tube cut in section, at the inner margin of the kidney, and therefore at the end of the section opposite the ureter Other structures which may or may not be seen in the section are —(7) the **collecting tubules** which connect the Bidder's canal with the ureter and therefore lie across the section towards its dorsal margin and (8) the **nephrostomes,** small funnel-like openings on the ventral side of the kidney communicating with the uriniferous tubules

(15) Sketch.

From the foregoing microscopic examination, it is seen that the kidney is made up of a large number of uriniferous tubules which in the section are cut in different planes, appearing therefore as circles or ovals or as paired parallel lines representing a split portion of the tubules The walls of the tube consist of an **epithelium** or single layer of cells, the lumen of the tube being, therefore, *intercellular* The interstices of the tubes are filled up by a connective tissue in which run the blood vessels, nerves, etc A network of capillaries derived from the renal artery and the renal portal vein creep over the uriniferous tubules and ultimately collect in the renal veins. Each uriniferous tubule has the structure shown in Figs. 17 & 18. We may trace a tubule from the ventral end where it begins in a dilated bulb called the Malpighian capsule It is made up of thin epithelial cells. A knot of capillaries arising from the renal arteries called the glomerulus pushes into the end of the bulb and gives rise to a double-walled sac called the Bowman's capsule occupied by the glomerulus itself. After being thrown into several convolutions, the tubule opens dorsally into the transversely placed collecting tubules Several collecting tubules open into the ureter which lies along the outer margin of the kidney The collecting tubules originate from a very narrow canal called the Bidder's canal lying along the inner margin of the kidney The vasa efferentia open into the Bidder's canal The sperms and the urinary matter take the same course after they have reached the collecting tubules The nephrostomes are small ciliated funnels placed on the ventral side of the kidneys They open from the coelom into the branches of the renal vein, allowing the flow of lymph from the coelom into the venous system, as we have seen in the case of lymph hearts (Sect 44)

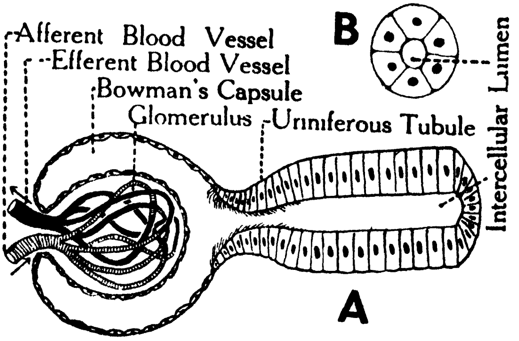

Fig 17 **A**, a diagrammatic longitudinal section of a Malpighian capsule with the teminal portion of the uriniferous tubule, **B**, cross section of a uriniferous tubule

49. The Kidney, a Gland.—The function of the kidney as an organ for separating out from the blood the nitrogenous waste of the body depends upon the ability of the cells of the uriniferous tubules to filter out these waste products from the blood supplied to the organ The cells have the specific power of eliminating the nitrogenous waste and certain salts as well as water in which these are dissolved to form **urine.** The kidney is therefore a gland which we define as a group of epithelial cells which are capable of removing from the blood certain specific substances resulting from the break-down of the protoplasm of the body. Now, the molecules of which this protoplasm is made are very complex, and contain carbon, oxygen, hydrogen and nitrogen, in addition to several others like potassium, sodium, calcium, phosphorus, sulphur, etc. As a result of the internal respiration or tissue oxidation the protoplasmic molecule is broken up into several simpler molecules. Just as, when a building is broken up, much of the wooden material can be rebuilt into a new building, while some can be used only as fuel, but the bricks, mortar, etc., become useless and have to be cleared from the site, so, in the

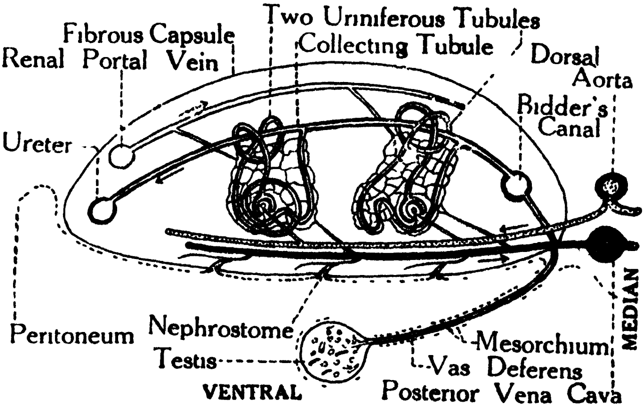

Fig 18 A diagrammatic transverse section of the kidney of the frog, showing two uriniferous tubules and their relation to the blood vessels Veins, dark , arteries dotted, renal portal vessels, unshaded

breaking-up of the living molecules or biogens, some of the resulting simpler molecules come in handy for the reconstruction of the protoplasmic molecule, while others happen to be suited for the manufacture of certain substances useful in the economy of the body, and yet others have to be eliminated from the body, being not only not useful, but positively harmful if long retained in the system. All these molecules pass into the blood and travel all over the body in the blood stream, and each gland takes from the blood supplied to it the substances necessary for manufacturing its particular secretion Certain of the useful substances may be permanently retained in the body in the form of deposits, as in the case of calcium carbonate and phosphate found in bone Some of these secretions are useful, e. g., the gastric juice, while others like urea are harmful and have to be expelled from the body. A harmful secretion is usually distinguished as an excretion.

50. The Excretory Function of the Kidney.—The function of the kidney is to eliminate from the blood, substances that form the urine. The important constituents of urine are **urea** and **uric acid** along with a number of inorganic salts, the chief among which is common salt In the frog the kidney receives blood from two sources, viz., the renal portal veins and the renal arteries, both of which contain blood rich in nitrogenous waste The blood from these vessels is brought into close association with the uriniferous tubules and the Malpighian capsules by means of the capillary net-work and the glomerulus respectively The Bowman's capsule and the uriniferous tubules separate from the blood of the respective capillary system the constituents of urine, viz , water, urea and salts

51. How Urine is expelled from the Body.—The course taken by urine is as follows —Uriniferous tubules— collecting tubules —ureter—cloaca—urinary bladder—cloaca—outside The force required for driving the urine down the uriniferous tubules is provided by the beating of the extremely minute protoplasmic processes or **cilia** which arise from the inner ends of the cells of the epithelium The cilia are capable of beating strongly in one direction and of slowly regaining their normal vertical position They are found in the neck of the Malpighian capsules and at other points along the lumen of the uriniferous tubules A current is set up by the beating of the cilia in unison in the direction in which the urine is to pass, that is towards the collecting tubules From the collecting tubules the urine reaches the ureter and trickles into the urinary bladder. The urinary bladder when full contracts by muscular activity and expels the urine in jets.

52. Other Excretory Organs.—The lungs and skin may be included in the category of excretory organs since they expel the waste product, carbondioxide, from the body Urea is formed in the liver Besides, the liver produces a number of waste products which are passed out into the alimentary canal in the bile secreted by it. (See Sect. 409).

Faecal matter is sometimes referred to as 'excreta,' when it should be understood only in a general sense It is mostly made up of indigestible refuse and it is not formed by a process of secretion or excretion It contains, however, such excretory matter as is secreted by the liver and passed into the alimentary canal

REVISION QUESTIONS

59 When is the frog's food scarce and when is it abundant? On what factors does the size of the fatbodies of a frog depend?

60 Enumerate the excretory organs and the genital organs in the last dissection Which are the essential and which the accessory excretory or genital organs?

61 What is a cloaca? To which system of organs would you assign it? Which are the products entering it in the male frog and in the female frog? Which of these are waste products and which useful?

62 Excretory matter, sperms, ova Mention where each of these is produced and trace the path of each to the outside

63 Where and how does excretory matter originate? What is its chemical composition? How does it reach the excretory organs?

64 What is the nature of the blood, arterial and venous, entering or leaving the kidney?

65 If a length of valve-tubing is irregularly folded up and embedded in wax and then the wax cut across, what figures would be formed by the cut ends of the tubing?

66 Describe the gross anatomy of the urinary organs

67 What is the nature and composition of urine?

CHAPTER 9

METABOLISM

53. Sources of Loss and Gain of Weight of the Body.— We have seen that the body of an animal like the frog gives out carbondioxide in breathing, nitrogenous waste matter in the urine, and water in both A large quantity of water is also lost by evaporation from the skin The outermost layer of the body of the frog is constantly peeling off in flakes of flat epidermal cells The loss of weight thus sustained by an animal can be determined by carefully weighing the animal, and reweighing it after the lapse of a specified period during which no food or water has been given to it.

In all normally healthy individuals, the weight of the body, however, does not vary within wide limits This means that the loss sustained is about equal to the gain The body gains weight on account of the food including water and oxygen.

54. The Composition of the Body.—The following tabular statement shows the important constituents of the human body with their chemical composition and the percentage of their weight.

TABLE I

COMPOSITION OF THE BODY

CONSTITUENTS	CHEMICAL COMPOSITION		PERCENTAGE OF WEIGHT
Water	H_2O	(Inorganic)	64
Proteins	Complex compound of H, O, C and N	(Organic)	16
Fats	H, O and C	(Do)	14
Salts	NaCl	(Inorganic)	5
Carbohydrates	e g , $C_6 H_{10} O_5$	(Organic)	1

It will be noted that the important elements that enter into the composition of the body are hydrogen, oxygen, carbon and nitrogen The various articles of food taken by an animal are also made up of exactly the same elements, and take the form of proteins, fats, salts carbohydrates and water The important waste products also contain these elements Thus

Carbondioxide	CO_2
Water	H_2O
Salts	Fe, Ca, K, Na, Ph, Cl, S, etc
Urea	$(NH_2)_2CO$
Uric Acid	$C_5 H_4 N_4 O_3$
Epidermal Matter	C, H, N and O

However, the composition of the substances that leave the body is not the same as that of those constituting the body and of those which form the food of the animal, except in the case of water and some of the salts The protoplasm of the body and the proteins of the food, for example, are very complex substances with a very large number of atoms in each of their molecules, while urea, carbondioxide and other waste products are very simple chemical substances In other words, the waste products are the result of the decomposition of the more complex substances of the body. This decomposition is essentially a process of oxidation by the atmospheric oxygen that is breathed in by the animal.

55. The Analogy of a Candle Flame.—The various chemical changes that take place in the body may be compared to those in a candle flame A flame, however, steady and constant it may appear, is really only the centre and expression of a double-sided change. On the one side the wax of the candle is converted into a gaseous condition, and on the other the gas is oxidised by the atmospheric oxygen under the temperature of ignition of the gas The steady flame is the result of these two processes taking place side by side in harmony The result of the oxidation or combustion is the production of heat and light as well as of simpler compounds like water and carbondioxide from the more complex molecules of the gas In the living body, the food is converted into the protoplasm on the one hand, and on the other the protoplasm undergoes oxidation or combustion. Since the biogen molecules contain nitrogen in addition to carbon and hydrogen, the products of its combustion necessarily include a nitrogenous compound, viz, urea, in addition to carbon dioxide and water Life is sustained in normal condition when these two processes take place side by side in harmony

56. Metabolism Anabolism—Katabolism.—The sum total of the chemical processes that take place in the living body is called metabolism The process of building up the biogen molecules is called anabolism, while that of the breaking down of the biogen molecules into simpler ones is called katabolism

We have seen that the food is digested in the alimentary canal and absorbed into the blood The blood vessels carry the absorbed food into every part of the body In the capillaries the plasma exudes out and passes into the intercellular spaces carrying with it the dissolved food Thus the individual cells of the body are fed From the food supplied to them they manufacture molecules similar to those which make up their own protoplasm In other words the cells manufacture more biogen molecules. This is known as **assimilation.** The natural result of the building up of more protoplasmic molecules is **growth** of the cells Thus feeding, digestion and absorption are subservient to assimilation and growth. In the young animal more protoplasm is built up than is broken down, which results in the growth of the young, while in the adult about as much is broken down as is built up, and consequently there is no increase in weight Assimilation and growth are thus the result of the anabolic processes that are always taking place in the body

But, side by side with the anabolic, the katabolic processes are also taking place In the capillaries of the blood system the oxygen of the oxyhæmoglobin is liberated This freshely liberated oxygen is used by the cells of the body for tissue respiration or **internal respiration,** to which, as we have already seen, the various respiratory movements and the pulmonary and cutaneous respiration are subservient Protoplasm is a very complex compound, and each biogen molecule is estimated to contain about a thousand atoms Internal respiration results in the breaking down of the complex molecule into carbon dioxide and water and into urea, a compound of nitrogen, hydrogen and oxygen. The oxidation of the protoplasm also results in the evolution of a large amount of heat, just as when a candle burns heat is evolved Tissue oxidation being slower than the burning of the candle, the heat is not intense and consequently there is no light as in the candle The production of waste materials of the body and heat are the result of the katabolic processes that are always taking place in the body

57. The Rate of Metabolism.—The rapidity of any chemical action depends upon several factors The *temperature of the medium* in which the animal lives is one of the most important of these The frog is a cold-blooded animal, that is, its temperature varies with that of the environment (poikilothermous) The rate of the chemical processes inside the body will be high or low according as the temperature is high or low In extremes of temperature, however, these chemical activities cease altogether. Consequently in the very hot season in India, frogs have to burrow underground in order to protect themselves from the excessive heat On the other hand in the very cold season food becomes very scarce and the cold weather makes it necessary for the animal to generate a large amount of heat This, however, becomes impossible as food is not abundant. Consequently the animal burrows into the ground and remains in a torpid condition protected from the cold and living upon what reserve of food it may have stored up when food was abundant As a result, therefore, of the high or low temperature of the medium, the rate of metabolism is reduced considerably and the animals enter upon a torpid condition, known respectively as summer sleep or **aestivation** and winter sleep or **hibernation.**

Since it is the food that is built up into protoplasm, the rapidity of the metabolic changes will also depend upon the *amount of food*, that is taken by the animal In the absence of food the metabolic processes will gradually slow down until ultimately they come to a standstill The *nature of the food* also determines the rapidity of metabolism Certain food substances like sugar yield more calories of heat than others when oxidised Thus, if a certain quantity of protein produces 40 calories, an equal quantity of fats produces 41 and sugar 94 calories Thus a sugar-rich diet would result in a larger amount of heat in the system, which in its turn would result in increased metabolic activity The *amount of work done* by the body and especially the voluntary muscles is yet another factor Work means expenditure of energy as well as production of heat When the muscles contract or the glands secrete, their biogen molecules are, so to say, exploding and liberating energy and heat In the case of muscles, the energy exhibits itself in the form of movements of contraction

REVISION QUESTIONS

68 What would happen to an animal under the following circumstances abundant food and no muscular activity , abundant food with muscular activity , insufficient food with muscular activity , low temperature, insufficient food and muscular activity ?

69 How is heat produced in the body ?

70 Why do you breathe heavily after muscular exercise ?

71 How do you account for the fact that the muscles, even though they produce a large quantity of heat, do not become much hotter than other parts of the body during hard work ?

72 Account for the fact that a sweet drink is invigorating after hard exercise

CHAPTER 10

HISTOLOGY—THE MICROSCOPIC EXAMINATION OF SIMPLE TISSUES

Material for Study Tissues prepared as directed in the chapter , microslides of heart muscle, t s the femur of frog and t s spinal cord of the frog

58. The Microscopic Structure of the Body.—We have examined the anatomy of several parts of the body of the frog in the preceding chapters and in Section 48 we saw the minute or microscopical structure of the kidney It was found that the uriniferous tubules were formed of cubical cells which in the section appeared as squarish units, each unit representing the section of a cell. Every portion of the body is made of cells arranged in a definite manner as in the kidney, though the shape and arrangement of the cells vary in the different parts. According to the nature and arrangement of the cells, we recognise four kinds of cell-aggregations or **tissues.** In each of these tissues, we have cells of a particular nature held together in a particular manner, serving a particular purpose in the body. The common tissues are **epithelium, connective tissue, muscle** and **nervous tissue.** We shall proceed to examine each of these under the microscope

59. Epithelium.—(Fig 19) In epithelial tissue the cells are arranged in definite layers Epithelium forms the lining membranes of the various body spaces like the lumen of the gut, the coelom, etc. According to the nature of the cells forming the epithelium we recognise three distinct varieties of epithelium These are the columnar, the squamous and the ciliated eptihelium

(a) **Columnar Epithelium.**—Cut out a small length of the intestine from a freshly killed frog and leave it for over 24 hours in a mixture of methylated spirits to which twice as much water has been added (Raniver's Alcohol) Cut open the lumen of the intestine and scrape off a little of the internal lining with a sharp scalpel Transfer the scrapings to a slide, add a drop of water and put on a cover-glass Examine under the microscope

Practical work

Here and there in the field of the microscope we can make out isolated columnar cells of a more or less elongated conical shape In their natural position, the flat ends face the cavity of the intestine, while they touch each other by their sides and the more pointed ends rest upon the sub-mucosa lying under the epithelium itself. On turning the high power on one of the cells, it will be noted that it contains a granular nucleus. Some of the cells may be seen to contain a small droplet of mucus in a small space towards the free end of the cell. Such cells are called **goblet-cells.** Their function is to secrete the mucus A better idea of the natural arrangement of the columnar epithelial cells can be obtained by examining a prepared section of the intestine In it the cells will be seen arranged like bricks in an arch (Fig. 24, A).

(16) Sketch

(b) **Ciliated Epithelium.**—In this variety we get the free (exposed) ends of the cells covered with extremely minute protoplasmic filaments called **cilia.** Otherwise it resembles columnar epithelium The cilia are capable of beating sharply and quickly in one direction and of slowly regaining their original position

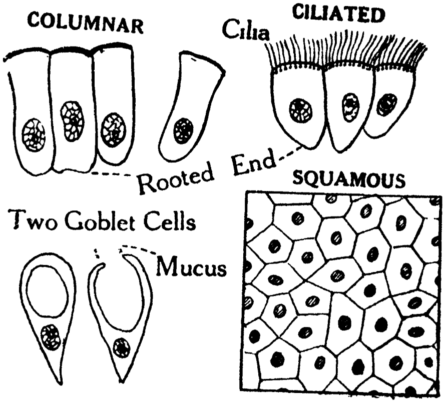

Fig 19 Epithelial Tissue of the frog The columnar and ciliated cells are seen from the side , the squamous from the surface

Practical work

Scrape the roof of the mouth of the frog with a sharp scalpel and transfer the scrapings on to a slide Add a drop of normal saline Cover with a cover-slip and examine under the microscope ✓

The cells cannot be distinctly seen, but the beating of the cilia, at first rapid, but slower and therefore better seen as the tissue is about to die, can be observed as an undulating motion Ciliated epithelium is found in several places in the body of the frog, e g., the mouth and throat, portions of the peritoneum, lining of the oviducts, nephrostomes, uriniferous tubules, ventricles of the brain and the surface of the body of the young larva

Sprinkle the roof of the mouth of a just chloroformed frog with finely powdered charcoal Observe what happens What is the purpose of the cilia? What is the direction of the beat of the cilia?

(17) Sketch.

(c) **Squamous Epithelium.**—Clean a scalpel well and with the end of the handle scrape the inside of your own cheek. Transfer

Practical work

the scrapings on to a slide and add a drop of water. Examine under the microscope under a cover-glass. ✓Note the large flat cells with a rather circular outline. Note the nucleus in the centre of each cell Squamous epithelium can also be obtained from the outer skin of the frog. Keep a frog in a small trough of water for a few hours It will be noted that the water contains larger or smaller flakes of the epidermis peeled off from the surface of the body Take a very small piece of this and examine under the microscope.

Note the flat cells fitting together like the tiles of a pavement. On account of this arrangement of the cells this kind of epithelium has also been called **pavement epithelium.** Each of the cells contains its own central nucleus

(18) Sketch

If a section of the skin be observed under the high power of the microscope we shall see that, next the surface, there are several layers of squamous or pavement epithelium, forming what has been termed **stratified epithelium** (See Fig 23)

60. Connective Tissue.—A sample of (a) **White Fibrous Connective Tissue** (Fig. 20, A) may be obtained from the delicate white membrane that binds the muscles together

Practical work

Carefully separate two of the muscles of the thigh of a freshly killed frog. Cut out a small piece of the connective tissue between them and spread it out by means of a pair of needles upon a clean dry slide Let the tissue stick to the glass in an extended condition Now place a drop of normal saline on the preparation and place a cover-slip upon it.

Under the microscope, we can make out a clear homogeneous substance or **matrix** of a gelatinous nature in which lie embedded two kinds of fibres the **white fibres** forming an irregular network of white wavy threads arranged in bundles, and the **yellow elastic fibres** sweeping across the field of the microscope and branching at intervals In addition to the fibres are the **connective tissue cells,** scattered among them

The matrix or intercellular substance occupies the greater portion of the connective tissue This is characteristic of all kinds of connective tissue. The cells are few and far between, while on the other hand in epithelial tissue there is hardly any matrix

(19) Sketch.

Other kinds of connective tissue are cartilage, bone, fatty tissue, etc.

(b) **Cartilage.**—Cartilage (Fig 20, B) is a tissue with a clear matrix of a dense and elastic nature in which are embedded cells.

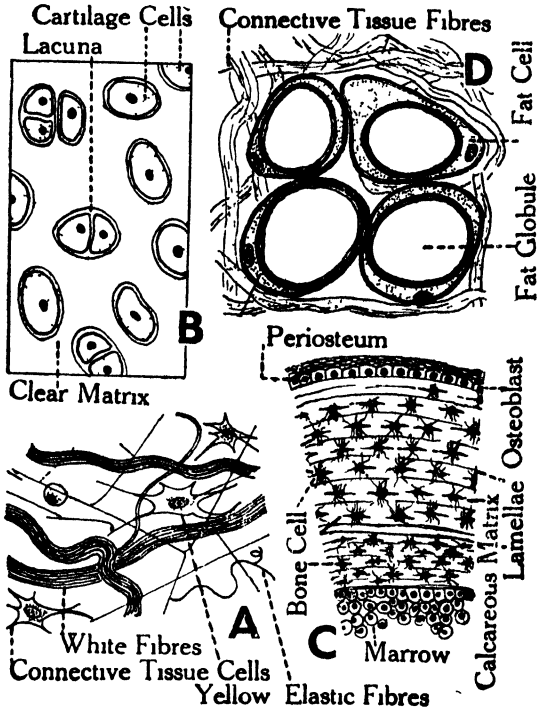

Fig 20 Connective Tissue **A**, white fibrous connective tissue, **B**, thin section of cartilage, **C**, portion of cross section of a long bone, **D**, adipose tissue

Practical work

Clean out the thin anterior end of the sternum which is made of cartilage, or slice off a thin section from the head of a long bone of a young frog Examine under the microscope on a slide with a drop of water under a cover-glass.

Note the clear hyaline **matrix** and the **cartilage cells.** Some of the cells may have been knocked out from the **lacunae** or little spaces in which they are placed, leaving them vacant Often, also, two cells may be seen together in the same lacuna indicating recent division of the cells The surface is covered by a layer of **perichondrium.**

(20) Sketch.

In certain portions of the cartilage in older frogs, calcareous deposits are laid down and consequently they appear to be harder and more brittle than hyaline cartilage The hyaline cartilage is then said to be converted into **calcified** cartilage

(c) **Bone.**—Bone (Fig 20,C) resembles cartilage in that it also has a matrix with embedded cells, but the matrix is harder and denser, being made of carbonate and phosphate of lime.

Practical work Examine a prepared section of the femur or other long bone of the frog under the microscope.

It will be noted that the matrix of bone is not homogeneous as that of cartilage In the centre is a large space containing the marrow of the bone. Outside this, the bony substance is arranged in concentric layers called **lamellæ,** with numerous **lacunæ** which contain the bone cells The cells are branched and adjacent cells anastomose, the lacunæ being connected together by fine canals or **canaliculi** inside which the processes of the cells lie Outside the bone is a layer of **periosteum.** The inner cells of the periosteum form a layer of special cells called **osteoblasts.** New bone cells are formed from the osteoblasts and consequently growth of bone is by addition from the surface.

(21) Sketch the t s of bone

If the vertebra of a frog is split into two, it will be seen that the core of the bone is spongy and not compact as in the section just examined. Hence we distinguish two kinds of bone, **compact bone** as in the long bones and spongy or **cancellous bone** as in the vertebræ, the heads of the long bones, etc.

(22) Sketch the broken surface of a vertebra

(d) **Fatty or Adipose Tissue.**—(Fig 20, D) This is made of cells swollen with fat globules In fatty cells, the nucleus with a small amount of protoplasm lies on one side of the cell, the rest of the protoplasm of the cell forming a thin cover over the fat globule Several small globules may be seen in certain cells. As the amount of fat formed increases, the small globules run together to form a large one. The fat bodies of the frog afford an example of fatty tissue and can be conveniently examined

Practical work

Mount a very small piece of the fat-body in normal saline, spread out with a pair of needles and gently place a cover-glass so as not to press heavily upon the preparation Note the fat globules invested in a thin layer of protoplasm with the nucleus.

(23) Sketch.

(e) **Blood** (See Sect 36) is often considered to be a form of connective tissue the cells of which are the corpuscles, and the intercellular substance the plasma.

61. Muscle.—The muscular tissue comprises three kinds of muscle—the striped, the unstriped and the cardiac muscles

(a) **Striped Muscle** (Fig 21, A) constitutes the larger muscles concerned with the movements of the body which are under the control of the will For this reason, it is also called **voluntary muscle.**

Practical work

Cut out a very small piece from one of the thigh muscles of a freshly killed frog Tease it out with the grain on a slide in a drop of normal saline It will be noted that the fibres of which the muscle is made up separate out fairly easily Under the low power of the microscope, they can be seen to be very long and cylindrical Observe a single fibre under the high power Note the alternate **light and dark bands** seen along the whole length of the fibre giving it a striated appearance. Careful examination under very high powers would reveal the presence of very fine **longitudinal fibrillæ** running the whole length of the fibre. Looking down the length of a muscle fibre, you

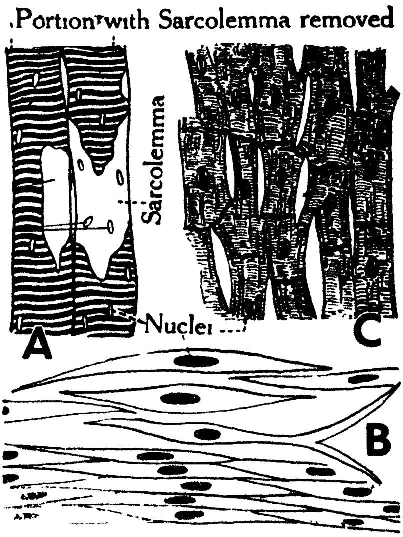

Fig 21 Muscular Tissue **A**, short lengths of two striped muscle fibres, with their sarcolemma mostly removed (X 50), **B**, a few isolated fibres and a portion of a sheet of unstriped muscle (X 450), **C**, cardiac muscle as seen in a section of the heart wall of a mammal

may happen to see a point where the fibre is crushed, and in that case, the thin outer membrane called **sarcolemma** may be clearly seen Add a drop of acetic acid to the slide and note how the several small elongated or spindle-shaped **nuclei** come more prominently into view. Examination along the edge of the fibre shows that these nuclei lie immediately under the sarcolemma.

(24) Sketch

(b) **Unstriped Muscle.**—(Fig 21, B) This is also called **involuntary muscle,** since this variety is found in those organs which are not under the control of the will A sample of this muscle may be prepared from one of the internal organs like the alimentary canal or the bladder

Practical work

Keep an inflated bladder of the frog overnight in Ranver's fluid Cut it open and scrape off the inner epithelium by means of a brush. Cut out a small piece of the bladder on to a slide and tease out well in a drop of water Examine under the microscope Note the elongated muscle fibres with tapering ends and a single nucleus for each cell Some of the cells may have branching ends Note also how the fibres interlace to form a sheet

(25) Sketch.

(c) **Cardiac Muscle.**—(Fig 21, C) The muscular tissue of the walls of the heart is different from both the above Examine a prepared slide of heart-muscle under the microscope Note the short striped fibres each with but one nucleus The ends of each cell are branched and the branches of contiguous cells are connected together to form a network.

(26) Sketch.

62. Nervous Tissue.—The nervous system is made up of nerve cells (Fig 22) or **ganglion cells** with their very long protoplasmic processes called **nerve fibres.** The nerve fibres are bound together by connective tissue into bundles which are called nerves In the brain and spinal cord, the ganglion cells and nerve fibres are supported and held together by a delicate tissue called **neuroglia.**

(a) **Ganglion Cells.**—Examine a prepared transverse section of the spinal cord of the frog or other animal and note the nucleated

Practical work

cells (See Sect 99) Note their irregular outline (Fig 22, A) indicating a number of processes These processes are branched, unlike the nerve fibre which arises also from the cell Hence they are called **dendrons** while the nerve fibre is distinguished as the **axon** or **axis cylinder.** Similar cells are also found in the brain In the ganglia the cells are devoid of the dendrons (Fig 22, B) They have only a single process arising from each, viz , the axis cylinder Hence they are distinguished as the **unipolar** cells from those of the brain and spinal cord These latter have several dendrons in addition to the axis cylinder, and hence they are called **multipolar.**

(27) Sketch a multipolar cell from the t s of the spinal cord

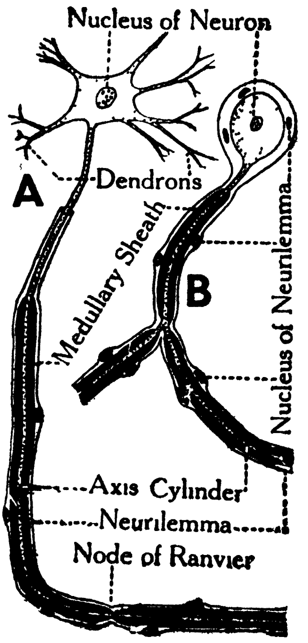

Fig 22 Nervous Tissue **A**, a multipolar nerve cell from the spinal cord together with the nerve fibre arising from it, **B**, a unipolar nerve cell from a spinal ganglion with its nerve fibre

Practical work

(b) **Nerve Fibres.** — Cut out a small length of a nerve of the frog, say from the sciatic plexus (See Sect 101) and tease it out with the grain on a slide in a drop of normal saline Note the connective tissue called **perineurium** which binds the fibres together Examine a single isolated fibre under the high power and note the white sheath covering it called **medullary sheath ;** the constrictions at intervals in the medullary sheath called **nodes of Ranvier** showing the **neurilemma** or the thin external membrane covering the medullary sheath , and the central protoplasmic **axon** or **axis cylinder** which arises directly from the nerve cells of the nerve centres

(28) Sketch.

The medullary sheath and neurilemma, which are supposed to act as an insulator for the axis cylinder make their appearance only outside the nerve centres When an axis fibre is traced on to the ganglion cell from which it arises, it will be seen, therefore, that as the fibre enters the ganglion, spinal cord or brain as the case may be, it loses its sheaths Nuclei are found immediately beneath the neurilemma, suggesting thereby that this outer sheath is made of much flattened cells The medullary sheath is made, not of protoplasm, but of fatty matter It therefore follows that only the axis cylinder is to be considered as part of the nervous tissue in the strict sense. Indeed both the neurilemma and the medullary sheath do not arise from the ganglion cells, but from the mesoderm of the animal

REVISION QUESTIONS

73 Define the terms, Tissue, Organ and Organism

74 In what parts of the body do you expect to find squamous epithelium, ciliated epithelium and columnar epithelium ?

75 Under what class of tissue would you include, blood, tendon, ligament, mucous membrane, uriniferous tubules ?

76 How does growth of cartilage and of bone take place ? In a section of a long bone we see concentric lamellae What do they tell you about the growth of bone ?

77 What do you mean by the term ' intercellular substance ' ? Indicate the amount and nature of the intercellular substance in each of the tissues you have examined How does the intercellular substance or matrix arise ?

78 When a nerve fibre is cut, the portion of the axis cylinder distal to the cut degenerates and is replaced by an outgrowth from the proximal part of the fibre What general principle is illustrated by this phenomenon ?

79 A striped muscle fibre contains several nuclei Do you consider it to be made up of several cells, or is it a single cell ? ✓

CHAPTER II

HISTOLOGY (Contd)—THE MICROSCOPIC EXAMINATION OF SOME COMPOUND TISSUES

Material for Study Micro-slides of vertical section of the skin, t s intestine, t. s stomach, t s kidney, section of liver and t s artery and vein of the frog

63. Simple and Compound Tissues.—In the preceding sections we have examined the different kinds of elementary tissues These are termed the simple tissues. When more than one kind of simple tissues are combined in any part of the body so as to form the organs, we get what are known as compound tissues Simple tissues can best be studied by examining the dissociated cells, compound tissues are, however, studied with advantage by means of sections of the tissues in which the association of the simple tissues with each other is retained. We shall now proceed to examine sections of a few compound tissues.

64. Section of the Skin of the Frog.— (Fig 23) Examine a prepared transverse section of the skin under the microscope.

Practical work

Since the section passes at right angles to the surface of the body it must show all the various layers of the skin, the the deeper as well as the superficial Note that the section shows two well-marked regions, the outer of which is the epidermis and the inner the dermis The deep portion of the **epidermis** shows a layer of distinctly columnar cells, with well marked nuclei, known as the **Malpighian layer.** The cells external to this become progressively flattened until the most superficial layer becomes the **squamous epithelium** (See Sect 59, C) Thus the epidermis is an example of stratified epithelium The outer flat cells are derived from the inner Malpighian layer As the cells of the latter become worn out, they are displaced by new cells, and as they pass to the surface they become dead, hard and horny and owing to mutual pressure they are flattened and converted to squamous epithelium Between the outermost layer and the Malpighian layer, we thus note, the transition from the columnar to the squamous type of epithelium

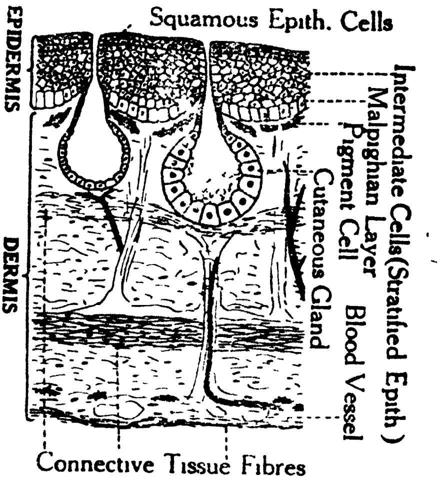

Fig 23 Vertical Section of the skin of the frog, diagrammatic (× about 150)

The **dermis** is made up of **connective tissue** in which horizontal and vertical fibres can be made out Irregular **pigment cells** are found in the region next inside the Malpighian layer and at the deeper levels. The colour of the skin is due to these pigment cells. **Blood vessels** and **nerve fibres** also may be made out in the dermis.

It will also be seen that there are certain flask-shaped structures, the **cutaneous glands** embedded in the dermis. If a number of these are examined you will realise that their necks pass out and open on the surface and that the epithelium which lines the bulb is continuous with the Malpighian layer. This means that these glands have arisen as invaginations or down-growths of the Malpighian layer into the subjacent dermis

(29) Sketch

Practical work

65. Section of the Intestine.— (Fig 24, A) Examine a prepared transverse section of the small intestine (See Sect. 15). Under the low power, the various simple tissues of which the thickness of the wall is made can be distinguished. Into the lumen of the canal project a number of ridges representing the folds inside. Under the high power the **mucous membrane (mucosa)** consisting of a layer of columnar epithelium can be made out The cells of this epithelium are of two kinds the **goblet cells** (Fig 19) containing large oval vacuoles filled with a transparent granular substance which is supposed to give rise to the mucus, and the others the **absorptive cells** whose function is to absorb the digested food Immediately outside the epithelial layer is the **submucosa,** a layer of connective tissue with connective tissue fibres, blood vessels, lymph spaces and nerves. Outside this is the muscular layer consisting of an inner layer of **circular muscle** fibres (unstriped) which are disposed transversely and an outer layer of **longitudinal muscle** fibres in which the cut ends of ~~the~~ fibres alone can be seen The longitudinal muscle is much thinner than the circular. Outermost is the **peritoneum** consisting

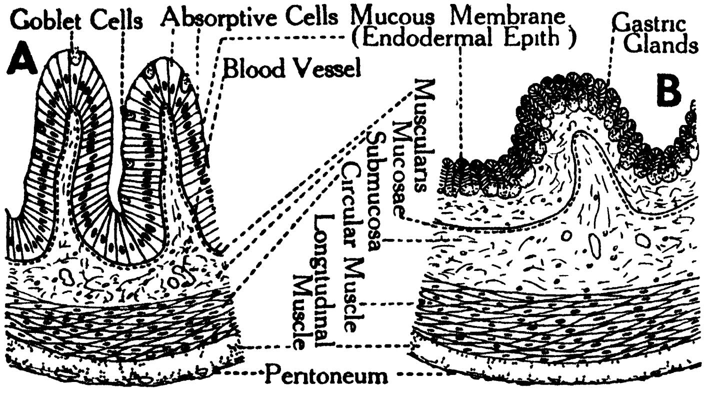

Fig 24 Portion of transverse section, **A**, of intestine, **B**, of stomach of the frog (Modified from Howes)

of a thin layer of connective tissue covered by a squamous epithelial layer.

(30) Sketch

Practical work

66. Section of the Stomach.—(Fig. 24, B) Examine a transverse section of the stomach, and note the various layers as in the section of the intestine The mucous membrane of the stomach is, however, much thicker than that of the intestine Examine a portion of this layer under the high power.

It will be seen that the thickness of the layer is due to the fact that the epithelium sinks into the supporting connective tissue so as to form a number of close set pits, simple or branched These pits or invaginations are the **gastric glands.** Immediately outside the mucosa is the **muscularis mucosæ,** a thin layer, composed of an inner layer of circular and an outer layer of longitudinal muscle fibres. This is followed in order by the **submucosa, circular muscle, longitudinal muscle** and **peritoneum** as in the section of the intestine .

(31) Sketch

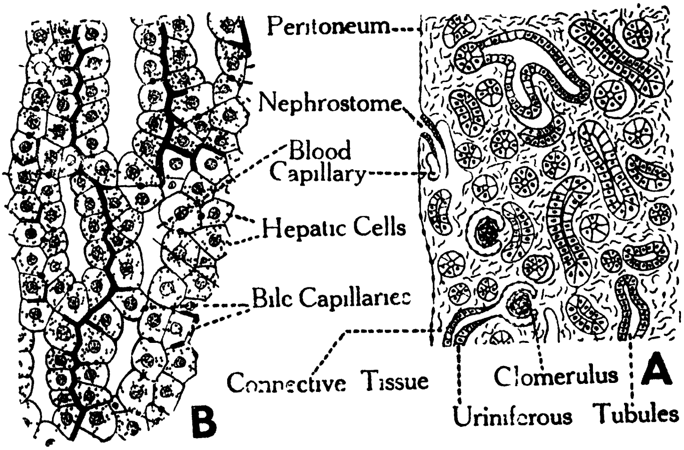

Fig. 25. Sections of small portions of **A**, kidney, **B**, liver, of the frog. (Modified from Howes)

67. Transverse Section of the Kidney.—(Fig 25, A) Re-examine the section studied in Sect 48, and make out the epithelial tissue, connective tissue, blood capillaries, epithelium of the ureter, etc.

68. Section of the Liver.—(Fig. 25, B) Examine a prepared section of the liver under the microscope.

Note the large many-sided (polyhedral) **hepatic cells** arranged more or less in regular columns We can make out on one side of each row an extremely narrow canal, the **bile capillary** while on the other side there may be either a **blood capillary** or an adjoining row of hepatic cells. The bile capillaries are intercellular channels bounded by the hepatic cells, and if the section happens to show a transverse cut of a bile capillary, the tubular nature of these hepatic glands will be readily appreciated Each capillary receives several tributaries called **bile passages** originating between adjacent cells of the same column. Several bile capillaries unite to form a small bile duct, and these unite to form larger and still larger ones. Several such unite together to form the bile duct.

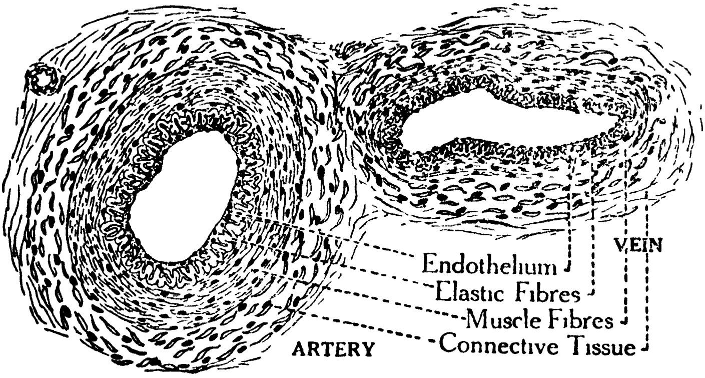

Fig 26 Transverse section of an artery and vein lying side by side

(32) Sketch.

69. Transverse Section of Artery and Vein.— (Fig 26) Examine under the microscope prepared sections of the artery and vein of the frog or other vertebrate

Note that the artery has a much thicker wall than the vein. In both there is (1) an epithelium of flat cells lining the lumen of the vessels called **endothelium,** followed by (2) a layer of circular **elastic fibres** seen in the sections as a wavy cord (1) and (2) form what has been called the inner layer or tunica interna Outside this comes (3) a layer of **circular muscle** in which elastic fibres are also present. This is the middle layer or tunica media. Outermost is

(4) a layer of **connective tissue,** also containing elastic fibres and constituting the outer layer or tunica externa

The muscle and elastic fibres by their contraction reduce the diameter of the blood vessels, especially the arteries The elastic fibres recoil in virtue of their elasticity every time the artery is dilated by blood pumped into it by the heart (cf Sect 398) The muscle on the other hand, being under the control of the nervous system, contracts only in response to impulses received by way of the vaso-constrictor nerves (cf Sect. 114)

As the artery branches into smaller and smaller vessels the thickness of the muscular and elastic fibres as well as the outer connective tissue coat is gradually reduced and ultimately lost so that the capillaries consist of but the endothelium This makes the diffusion of gases and liquids through the capillaries easy.

(33) Sketch

REVISION QUESTIONS

80 What is the relation between an epithelium and a gland ?

81 What are the various glands you have come across in the foregoing chapter ? Which of them would you describe as epithelial, tubular, saccular, compound (racemose)?

82 Enumerate the tissues that go into the formation of blood vessels, intestinal wall, kidney, skin

83 Explain why the arteries appear much thicker than veins in transverse sections

84 What do you mean by pulse ?

CHAPTER 12

THE SKELETON — PREPARATION OF THE SKELETON — THE SKULL — INVESTING AND REPLACING BONES

Material for Study. A killed frog for each student, a mounted skeleton of the frog

70. Preparation of the Skeleton.—(Fig. 27) Open the abdomen of the frog up to the point where the abdominal vein dips into the liver, and cut out as much of the internal viscera as possible. Dip the entire body of the animal except the *right* fore and hind limbs in boiling water for 15 minutes Procure a mounted skeleton. On a piece of card-board make a ground plan of the *left* fore and hind limbs.

Practical work

Pick out as much of the muscle from the entire body including the right limb, as is necessary to expose the rough skeleton. Avoid removing or injuring the cartilaginous parts of the skeleton, especially of the pectoral girdle and the hyoid apparatus. Cut out the entire left fore and hind limbs and keep them aside safely.

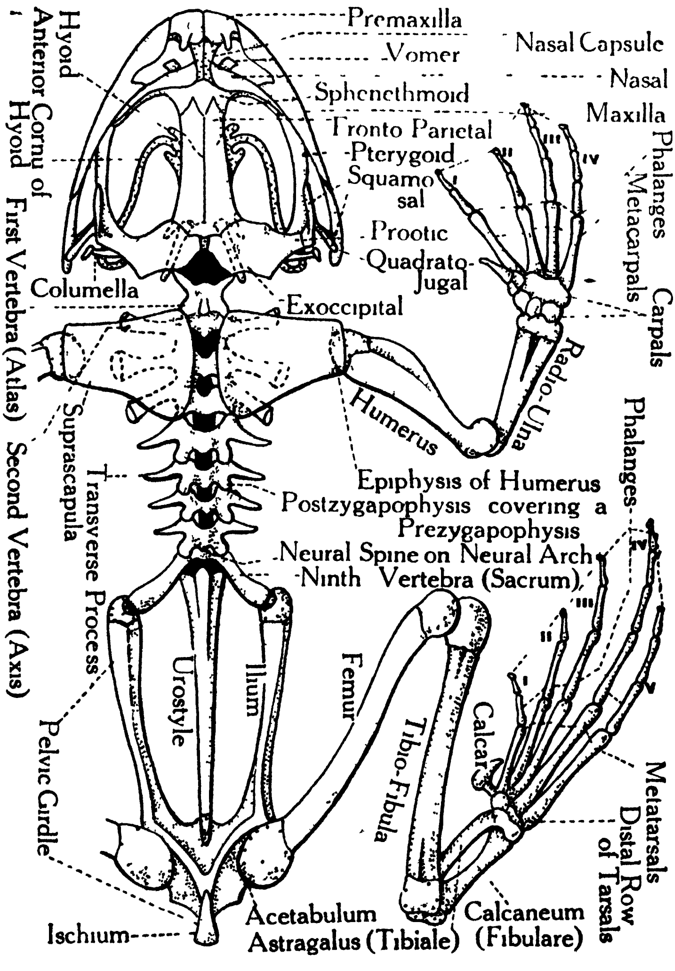

Fig 27 The skeleton of the frog from the dorsal side, excluding the left limbs Roman numerals indicate the numbers of the digits (Altered from Howes)

Now, divide the rest of the skeleton into the following parts :—
(1) head with the jaws, (2) vertebral column, (3) pectoral girdle with

the right fore-limb, (4) pelvic girdle with the right hind-limb and the urostyle (placed between the two halves of the girdle) and (5) the cartilaginous hyoid apparatus.

String the vertebrae on a piece of thin wire, in order, tie the ends of the wire together and scrub the vertebrae with a wire brush under the tap. The larger bones of the fore and hind limbs, the skull and the girdles may also be cleaned in a similar manner Take care lest the bones of the right hand and foot fall to pieces—it is intended that these should not be disarticulated Put the various bones aside to dry.

In the meanwhile, clean the well-macerated left fore- and hind-limbs, beginning with the larger bones and ending up with the small bones of the digits in order As each bone is removed and cleaned, place it in its correct position in the plan, fixing it, if necessary, with glue.

Arrange the various parts as nearly in their natural relations as possible

71. Parts of the Skeleton.—We can now divide the entire skeleton into the **axial skeleton,** including the skull, the jaws, the vertebral column and the urostyle, the **appendicular skeleton,** including the limb-girdles and the limb skeleton and the **visceral skeleton,** viz, the hyoid apparatus

72. The Skull.—(Figs 27 and 28) This is the skeleton of the head and lodges the brain, the hollow inside it being the brain case The **upper jaw** is closely associated with the rest of the skull or **cranium.** The **lower jaw,** on the other hand, is attached only at its hinder end, to the upper jaw. All along the margin of the upper jaw are fine teeth, with recurved points the **maxillary teeth.** The **vomerine teeth** are seen on the roof of the mouth in front (cf Sect 10) The **sockets of the eyes** form large vacuities in the middle on each side In front of each is the **olfactory capsule,** lodging the nostrils or olfactory organs, behind, the **auditory capsule;** and between the two is the cranium proper which lodges the brain. The entire skull, then, consists of the brain case, the capsules of the important sense organs and the upper jaw. In a well-cleaned skull the various bones can be distinctly seen.

(34) Sketch the dorsal and ventral views of the skull on the left and right halves respectively of a page, leaving room in between and all around

for labelling With the help of the following tabular statement and Figs 27 & 28, make out and label the various bones.

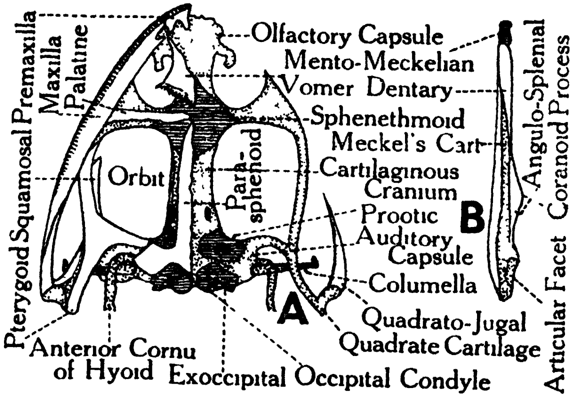

Fig 28 **A,** Ventral view of the skull, with the membrane bones removed from the left half, **B,** the right ramus of the lower jaw veiwed from the inner aspect Cartilage, dotted, cartilage bones, striped, membrane bone, unshaded

TABLE 2

73. THE BONES OF THE SKULL, JAWS AND HYOID

REGION	NAME OF BONE OR CARTILAGE	SINGLE OR PAIRED	NATURE OF ORIGIN	BRIEF DESCRIPTION
Cranium	Fronto-parietal	2	Investing	Dorsal, roofing
	Parasphenoid	1	do	Ventral, T-shaped
	Sphenethmoid	1	Replacing	Anterior, ring-like
	Exoccipital	2	do	Posterior, bears occipital condyles and foramen magnum
	Cartilaginous Cranium	1	Cartilage	Between Fronto-parietal and Parasphenoid, behind Sphenethmoid
Nasal	Nasal	2	Investing	Dorsal, flat, triangular
	Vomer	2	do	Ventral, flat, bears Vomerine teeth
	Nasal, or Olfactory Capsule	2	Cartilage	In front of Sphenethmoid, the two halves fuse mesially, enclose nostrils

REGION	NAME OF BONE OR CARTILAGE	SINGLE OR PAIRED	NATURE OF ORGIN	BRIEF DESCRIPTION
Auditory	Prootic	2	Replacing	Form anterior wall of auditory capsule
	Auditory Capsule	2	Cartilage	Fused to hind end of Cranium on each side, enclose ears
Upper Jaw	Maxilla	2	Investing	Elongated, bear teeth
	Premaxilla	2	do	Short, bear teeth, at tip of upper jaw
	Quadrato-jugal	2	do	Posterior end of jaw, comma-shaped
	Pterygoid	2	*Replacing	Between quadrato-jugal and auditory capsule, triradiate
	Palatine	2	*Replacing	Transverse, between sphen-ethmoid and maxilla
	Squamosal	2	Investing	Above pterygoid, triradiate
	Quadrate	2	Cartilage	Between squamosal and pterygoid, serve for articulation of the lower jaw, extend forwards to palatine region
Lower Jaw	Dentary	2	Investing	Outer, anterior, short
	Angulo-splenial	2	do	Inner, longer
	Mento-Meckelian	2	Replacing	Very small, forming symphysis
	Meckel's Cartilage	2	Cartilage	Between dentary and angulo-splenial, lying in a groove of the latter, extending up to articulation
Hyoid	Body of Hyoid	[illegible]	Cartilage	Between rami of lower jaw
	Anterior Cornu	2	do	Long, recurved, reaching auditory capsule
	Posterior Cornu	[illegible]	Replacing	Behind body of hyoid
	Columella	2	do	Small rod inserted into side of auditory capsule

*Partially ensheathed in investing elements in course of development

74. Investing and Replacing Bones.—Note that in the tabular statement ten bones are marked as 'investing' bones, eight as 'replacing' bones and the rest as cartilage. This means that the skeleton of the head consists of three different kinds of tissues. In the tadpole and the very young frog the skull and jaws are made entirely of cartilage and it is then called the **chondrocranium** (cartilaginous skull) which is invested by a membrane As the animal becomes adult, parts of this chondrocranium are converted into bone by the formation of centres of ossification which, so to say, grow all around eating their way into the cartilage In other words, parts of the chondrocranium are *replaced* by bony tissue to which the name **replacing bones** or **cartilage bones** has been given These, it will be noted, form part of the original skull of cartilage, though different from it in structure In the membrane which *invests* the chondrocranium also, centres of ossification appear, and as a result we get the **investing bones** or **membrane bones.** These naturally cover the original skull just as the membrane did, with the result that all of them are superficial They differ from the investing bones in origin and in disposition, though resmebling them in structure.

If, now, we can remove the membrane bones from the skull, the original chondrocranium that has been partly converted into replacing bone will be left behind.

Leave the skull in boiling water for another five minutes With the help of a scalpel lift off the membrane bones one by one from the left half of the skull, taking care not to injure the underlying cartilage (See Fig 28) Note the replacing bones and the cartilaginous portion of the chondrocranium.

Practical work

(35) Sketch your preparations, showing the left half without and the right half with the membrane bones, both dorsal and the ventral views.

Repeat for the lower jaw.

(36) Sketch.

CHAPTER 13

THE SKELETON (Contd)—THE VERTEBRAL COLUMN—GIRDLES AND LIMBS—HOMOLOGY—THE HYOID—BONE, ITS COMPOSITION AND FUNCTIONS

75. The Vertebral Column.—This is composed of nine bony rings or **vertebræ** and a long ploughshare-shaped bone or **urostyle**

at the hind end. The nine rings together form a tube, the **neural canal** in which the nerve cord lies.

Examine a typical vertebra, like the third (Fig 29, B) more closely

It has a body or **centrum** below the neural canal and a **neural arch** forming the sides and roof of the canal A **neural spine** projects upwards and backwards from the top of the arch Two **transverse processes** project outwards like the wings of an aeroplane On the anterior phase of the neural arch are a pair of articular facets, facing upwards, called the **pre-zygapophyses,** while on the posterior phase are a pair of similar facets which, however, face downwards, called the **post-zygapophyses.** The centrum is concave in front and convex behind and is therefore spoken of as *procoelous*

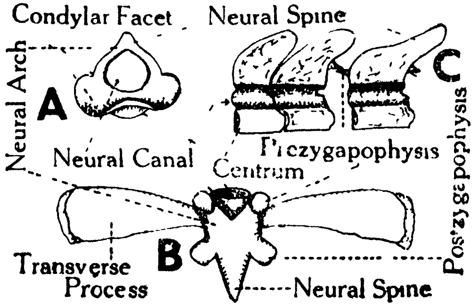

Fig 29 Vertebrae of the frog **A** anterior view of atlas, **B**, dorsal view of the third vertebra, **C**, three contiguous vertebrae in sagittal section, the intervertebral foramen is shown between the two approximated ones

The centra of the vertebrae articulate serially, the hinder convex face of each centrum fitting into the anterior concave face of the next posterior one In a similar manner, the post-zygapophyses of any vertebra articulate with the pre-zygapophyses of the vertebra immediately behind

Some vertebrae present peculiarities, which may now be noted:

The first vertebra or **atlas** (Fig 29, A) is devoid of transverse processes, centrum and pre-zygapophyses. The **eighth vertebra** has a biconave or *amphicoelous* centrum The **ninth vertebra** or **sacrum** has a convex anterior face fitting into the concave posterior face of the eighth The posterior face is also convex, but there are two projections fitting into similar depressions at the anterior end of the urostyle Dorsal to these depressions in the **urostyle** is a deep pit inside which the posterior end of the nerve cord lies, and which therefore corresponds to the neural canal of the regular vertebrae.

Between adjacent vertebrae are paired openings, the **intervertebral foramina** through which the spinal nerves pass out of the neural canal The tenth spinal nerves pass out through a pair of openings on the sides of the urostyle. One or both of these may sometimes be absent in the common frog, *Rana tigrina*

(37) Sketch the anterior and posterior views of the 3rd vertebra, the front view of the atlas, the hind view of the sacrum, and the lateral view of the urostyle.

76. The Pectoral Girdle.—(Fig 30, A) This is an incomplete hoop of bone and cartilage which girdles the chest region, embedded in the muscular bodywall. It consists of two symmetrical halves, meeting in the mid ventral line, but open in the mid dorsal region. Note that on each side the fore-limb is articulated in a socket called the **glenoid cavity.** Close examination reveals that the glenoid cavity is formed at the junction of three skeletal pieces Place the girdle in the natural position and identify the component parts The bone radiating upwards from the glenoid is the **scapula,** and inwards, downwards and along the posterior margin is the **coracoid,** the rest of the socket being formed of a cartilage extending forwards along the inner end of the scapula and then inwards, called the **procoracoid.** A small membrane bone called the **clavicle** is developed along the anterior side of this cartilage Dorsal to the scapula is a large flat plate of cartilage, partially calcified, called the **suprascapula.**

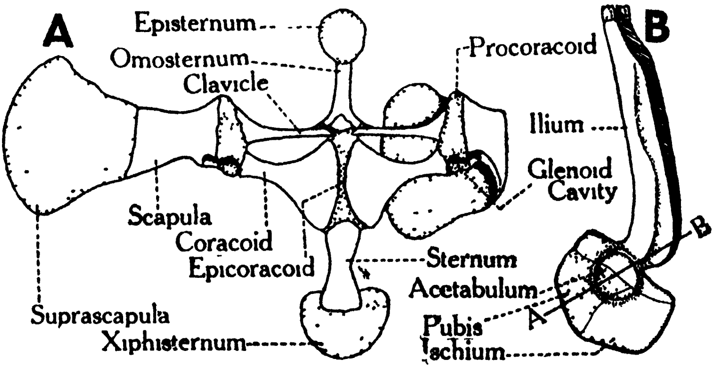

Fig 30 A, pectoral girdle of the frog from the ventral side, the left half extended flat, B, pelvic girdle seen from the left side The line AB marks the plane of section of the hip-joint shown in Fig 33

Between the two coracoids in the middle line are the cartilaginous **epicoracoids.** Between the procoracoid and the coracoid is a large vacuity or **fenestra.**

77. The Sternum.—This corresponds to the breastbone in man. It consists of four parts, two flat plates of cartilage at the ends and two bones in between Attached to the inner ends of the clavicles and projecting forward is the small λ - shaped bone called the **omosternum,** tipped by the flat cartilaginous **episternum.** At the posterior end of the coracoids and projecting backwards is the **sternum (metasternum)** tipped by the flat cartilaginous **xiphisternum.**

(38) Sketch the pectoral girdle and sternum from the ventral view On one side the suprascapula and scapula may be shown as if spread out

78. The Pelvic Girdle.— (Fig 30, B) Unlike the pectoral girdle, this is stronger and more compact The two long anterior processes of the girdle are attached to the transverse processes of the ninth vertebra by means of cartilaginous tips On either side of the body of the girdle is a concave depression called the **acetabulum** by means of which the hind limbs articulate with the girdle. As in the glenoid, this socket also is found at the junction of three skeletal pieces, two bones and one cartilage Of these, the anterior and upper one is called the **ilium,** continued forwards as the long process articulating with the ninth vertebra, the posterior one is called the **ischium** and the ventral cartilaginous one is called the **pubis.** The ilia, ischia and pubes of the two sides form a strong symphysis.

(39) Sketch the lateral view

79. The Fore Limb.—(Fig 27) Most of of the bones of the fore and hind limbs are what may be termed long bones and their ends are tipped or capped with cartilaginous pieces or heads called **epiphyses.** The proximal or nearest bone of the arm is the **humerus** with a well developed epiphysis for articulation with the glenoid. The bone of the fore-arm is the **radio-ulna.** In man it is represented by two distinct bones, radius and ulna, which in the frog are fused into one. Note the grooves along the bone indicating the line of fusion. Along the longer side of the bone is the ulna and along the shorter side the radius. Note the articular surface at either end.

The wrist region is formed of six short irregular bones arranged in two rows called **carpals.** Of these, the proximal row articulates with the distal end of the radio ulna and the distal row with the first row of bones of the hand region or **metacarpals.** These are five in number corresponding to the five digits or fingers, designated I—V. Of these digit I is the smallest and represents the entire rudimentary first digit or thumb (See Sect 3) II to V are much longer. The bones of the digits are called **phalanges.** Digits II and III possess two and digits IV and V possess three phalanges each. This is expressed in a digital formula as follows —0 2 2 3. 3, in which the figures give the number of phalanges respectively of digits I, II, III, IV and V

(40) Sketch the disarticulated, that is, the left, fore-limb, showing the various bones in correct relative positions, but not touching each other.

80. The Hind Limb.—(Fig 27) The proximal bone of the hind-limb is the **femur.** The head of the femur fits into the acetabulum Distally the femur articulates with the bone of the shank called the **tibio-fibula.** Like the radio ulna, it is a compound bone formed by the fusion of the two elements corresponding to the tibia and fibula of man The ankle region in the frog is very peculiar, being very much elongated It consists of four **tarsal** bones disposed in two rows The proximal row is formed by two very elongated tarsals, the **astragalus** (tibiale) on the side of the inner or first toe and the **calcaneum** (fibulare) on the side of the outer or fifth toe These two bones are held together by common epiphyses The distal row consists of two very small cartilaginous pieces Between the two rows of tarsals is the *intertarsal joint* unrepresented in the fore-limb. The tarsals are followed by a row of five **metatarsals** which are all elongated bones. In line with the distal tarsals is a spur-like projection consisting of two small bones. These constitute the **calcar** and represent the rudimentary inner digit of the foot. The bones of the digits are called **phalanges.** The digital formula is 2. 2. 3. 4. 3.

(41) Sketch the disarticulated, that is, the left, hind limb showing the various bones in their correct relative positions, but not touching each other.

81. Resemblance between the Girdles and between the Limbs.—We have noted in Sect. 3 how the fore and hind-limbs resemble each other. But the examination of their skeletons makes it clear that this resemblance is not merely external, but more fundamental, affecting even the internal organisation Besides, the girdles also are seen to show a fundamental resemblance to each other even though they differ so much in appearance (Study Fig 31) Both girdles have an articular surface with which the head of the humerus or of the femur, as the case may be, articulates In both three skeletal pieces enter into the formation of the articular surface, of which one is cartilaginous In both the right and left halves meet in a median symphysis. In both the dorsal elements, (scapula and ilium) are the most divergent, serving for attachment to the body In both the antero-ventral elements (procoracoid and pubis) remains cartilaginous, while the postero-ventral and dorsal ones are ossified In both the dorsal elements (scapula and ilium) are tipped with cartilage

The general resemblances between the fore- and hind-limbs and their girdles are expressed in the following tabular statement

TABLE 3

HOMOLOGY OF LIMBS AND GIRDLES

POSITION OF SKELETAL ELEMENT	NAME OF SKELETAL ELEMENTS IN	
	Pectoral Girdle	**Pelvic Girdle**
Dorsal	Scapula	Ilium
	Supra scapula	Cartilaginous tip of Ilium
Antero-ventral	Procoracoid and Clavicle	Pubis
Postero-ventral	Coracoid	Ischium
Articular Facet	*Glenoid*	*Acetabulum*
	Fore Limb	**Hind Limb**
	Shoulder Joint	*Hip Joint*
Proximal Series	Humerus	Femur
	Elbow	*Knee*
Second Series	Radio-ulna	Tibio-fibula
Third Series	1st row of 3 carpals	Tibiale, Fibulare
	Wrist	Ankle *Inter-tarsal joint*
Fourth Series	2nd row of 3 carpals	Distal row of 2 tarsals
Fifth Series	5 Metacarpals	5 Metatarsals and Calcar
Digits	Phalanges	Phalanges

82. Homology.—The relation between the fore- and hind-limbs and their girdles is now clear. The hind-limb and its girdle are, as it were, a repetition of the fore-limb and its girdle In the vertebral column also we note the same phenomenon. Each segment of the vertebral column or vertebra is, essentially, similar to any other vertebra In other words the vertebræ are serially repeated If we study the development of the various vertebræ, we shall see that they all resemble each other in the nature of their origin as well as in their general adult structure This is true of the limbs and girdles also. We express this by saying that the vertebræ are serially homologous structures, the fore-limb is homologous to the hind-limb, the pectoral girdle and pelvic girdle are homologous, etc

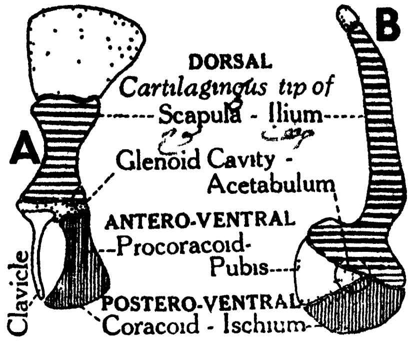

Fig 31 **A**, pectoral and **B**, pelvic girdle of the frog, showing the homology between them

We have noted that the shapes of the pectoral girdle and pelvic girdle are so unlike, that their homologies could be discovered only by a very close examination Now, the urostyle differs markedly from the vertebræ in shape, but it is seen by a study of the origin of that bone that it arises from the same tissue as that from which the vertebræ arise, and in a similar manner The fact that the neural canal extends into the urostyle suggests that it resembles the vertebræ. If, indeed, the urostyle is segmented transversely into several pieces, its resemblance to the vertebræ will be more apparent. We conclude, then, that the urostyle is the hinder part of the vertebral column which has remained unsegmented. From these we see that the origin, even more than the adult structure, is to be relied on in determining the homologies of the parts of the body

When we study the limbs or the vertebræ of the rabbit, we shall find that there is a close resemblance in the nature of origin and in the adult structure between them and the corresponding organs in the frog. We express this by saying that the fore-limb of one vertebrate is homologous to that of another, etc. In the same manner the hearts, lungs and other organs of the vertebrates are respectively homologous structures

83. The Hyoid Apparatus.—This is the plate of cartilage embedded in the muscles of the floor of the mouth, between the ramii of the lower jaw The flat plate is called the **body of the hyoid.** From its anterior side arise the pair of **anterior cornua,** long slender ribbon like cartilages which pass backwards and upwards on either side of the throat and join the prootic bones of the ear region The flat processes at the outer side of the bases of the cornua are the **alary processes.** The pair of processes arising from the postero lateral corners are the **postero-lateral processes** Diverging from the middle of the posterior margin are two bony rods called the **thyroid processes (posterior cornua).**

84. The Composition of Bone.—In Sect 60, c we have noted the microscopic structure of bone The intercellular matrix of bone is made up of carbonate and phosphate of calcium The amount of calcium salts in the bone increases with the age of the animal The result is that, whereas the bones of the young animal are softer and more elastic, those of the older animal become harder and more brittle

Practical work

Select two long bones of the frog, like the femur and steep one of them overnight in dilute hydrochloric acid and the other in a solution of potassium hydroxide Note the effervescence in the first due to the action of the acid upon the calcareous matter of the bone Remove and wash The acid has decalcified the bone and rendered it soft and elastic, while the alkali has dissolved out the organic matter (the bone cells) and rendered the bone light, porous and very brittle It is therefore seen that bone is made up of two substances, one of which renders it hard and strong, while the other confers elasticity to it

85. Functions of the Skeleton.—The skeleton serves to give attachment to the various voluntary muscles or their tendons, thereby making the various movements of the body possible. It gives rigidity and firmness to the body and its various parts. Besides the more delicate organs of the body such as the brain, spinal cord, heart, etc., are protected from injury by the skeleton.

REVISION QUESTIONS

85 What are the parts of the skeleton which afford protection to the brain, the spinal cord, the heart, the ear, the nose, the eye?

86 Why is it that fractured bones in young people are easier to unite (fuse), than in older people?

87. To which of the four different kinds of simple tissues would you assign bone and cartilage? Give reasons

88. Make a list of the parts of the skeleton formed of cartilage

80. All the long bones are tipped with cartilage The glenoid cavity and the acetabulum are also lined by cartilage What is the significance of this?

90 Where does each of the following articulate —Occipital condyles, transverse processes of the ninth vertebra, the anterior cornua of the hyoid? What is the nature of each of the joints involved?

91 The pelvic girdle is more compact, stronger and provided with a much better developed symphysis than the pectoral girdle Besides, it is directly articulated to the vertebral column What is the significance of these?

92 The long bones of the limbs are hollow What mechanical principle is involved in this?

93 Enumerate the various joints of the body of the frog

94. What advantage is gained by the segmented nature of the vertebral column? Suggest a reason for the unsegmented nature of the urostyle

CHAPTER 14

MUSCLES — JOINTS — MOVEMENT

Material for Study A freshly killed frog for each student; articulated skeletons of the frog and man, micro-slide of the hip-joint of a young frog

Practical work

86. Dissection of a Typical Muscle.—Strip the skin from the hind leg of a freshly killed frog laid on its back The muscles of the thigh and the shank are easily exposed By the help of a pair of needles separate the various muscles from each other carefully tearing away the fascia or connective tissue between them Make out the muscles with the help of Fig 32. One of these is the **gastrocnemius,** the large muscle on the inner side of the shank and corresponding to the calf-muscle of the human leg Separate this from the other muscles of the shank Note the thickest part of the muscle towards the middle referred to as the **belly** of the muscle At either end the muscle tapers, and as it does so the fascia or connective tissue

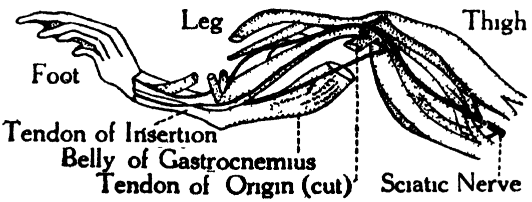

Fig 32 A dissection of the muscles and nerves of the hind-limb of the frog

binding it gradully passes into a dense, white, inelastic, and very strong cord called a **tendon.** Dissect the tendons at both ends. Note that the proximal one takes its **origin** from the region of the knee-joint, being attached partly to the distal end of the femur and partly to the proximal end of the tibio-fibula The distal tendon is inserted on the plantar side (sole) of the foot, becoming thin and flat as it approaches its **insertion.** In both cases the tendons gradually pass into the connective tissue or periosteum binding the bones to which they are attached When the muscle contracts the distal tendon is drawn towards the proximal tendon The latter, being the relatively less movable, is called the **tendon of origin** and the former, the relatively more movable, is the **tendon of insertion.**

(42) Sketch.

87. Action of a Voluntary Muscle.—Remove the nail fastening the hind-limb which you have dissected Give a sharp pinch on the belly of the gastrocnemius muscle

The muscle, if still alive, will suddenly contract, becoming thicker at the belly and shorter in length, without any change in volume This is the result of the contraction of the component fibres of the muscle Its effect is to bring the two ends of the muscle towards each other, thereby causing the mutual approximation of the two bones to which they are attached More often, however, it is a movement of one bone upon the other, since the bone of origin of the muscle is relatively immovable

In the case of the gastrocnemius muscle of the frog the effect of contraction is the straightening out or extension of the foot as if in jumping or paddling in water Another effect also may be produced by the contraction of the same muscle Keep the knee-joint extended and stimulate the muscle again by pinching Since the origin is partly on the distal end of the femur the effect of the contraction is also to pull the leg towards the thigh, causing the flexion or bending of the shank upon the thigh about the knee joint. Thus the gastrocnemius muscle acts as a **flexor** of the leg or shank and as an **extensor** of the foot.

The action of voluntary muscles can conveniently be illustrated also by a few examples from human anatomy (Fig 33) The biceps muscle of the arm has its origin by a double tendon from the scapula and its insertion by a single tendon from a point on the radius about an inch and a half from its head (A) When the muscle contracts, the radius is brought nearer the scapula. But since the radius can only rotate about the distal end of the humerus, the result of the contraction is to bend the fore-arm on the upper-arm in such a manner as to bring the hand near the scapula

It will be seen that here we have an example of a *lever of the third order*: the elbow joint forms the fulcrum upon which the radius, which is the lever, moves. The fore-arm and any object that may be carried in the hand form the weight The contraction of the muscle supplies the power which acts on a point between the fulcrum and the weight. Other kinds of levers also are illustrated by the human body. Raising the body on the toes is an example of a *lever of the second order* (B) The calf muscle has its origin at the lower end of the femur and the upper end of the tibia and fibula, and its insertion on the heel-bone The tip of the toe touching the ground is the fulcrum, the weight of the whole body acts on the ankle joint and the power is supplied by the contraction of the strong calf-muscles The power and fulcrum are at either end of the lever (foot) and the weight is between the two. A *lever of the first order* is illustrated by the head rocking on the atlas (C). Here the fulcrum is formed by the facets on the atlas against which the condyles work The power is supplied by the contraction of the muscles of the back of the neck and the weight is that of the front part of the head. The fulcrum in this case is between the weight and the power When the muscles of the back of the neck contract the face is lifted up. The power and the

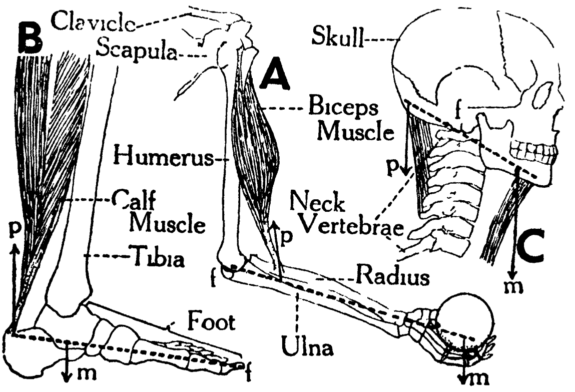

Fig 33 To illustrate the levers of the human body **A**, raising the forearm and hand about the elbow, **B**, raising the body on the toe, **C**, rocking the head f, fulcrum, m, mass or weight and p, power generated by muscular contraction

weight may, in this case, change places, and the alternate contraction of the muscles of the back of the neck and of the front of the neck results in the rocking movements of the head.

88. Other Effects of Muscular Contraction.—Muscles, when stimulated, invariably contract pulling their ends nearer to each other, as we have seen above But the contraction of muscles can produce various movements other than flexion and extension This depends upon the nature of the joints and the manner in which the muscles are attached to the respective bones Thus there are muscles which pull the limbs towards the median line called **adductors,** those which have the opposite effect being the **abductors.** Then again, there are **levators** or muscles which raise, for example, the lower jaw, those that depress the jaw being called **depressors.** Or again, there are muscles which cause the rotation of one part, for example, a limb upon its axis, called **rotators.**

89. How Muscles are stimulated.—In Sect 86, we caused the muscle to contract by pinching it In other words, a mechanical **stimulus** was applied to the muscle in order to induce it to contract A drop of acid placed on the muscle or the application of heat or the passing of a current of electricity may similarly induce the contraction of the muscle In nature, however, muscles are stimulated by **nerve impulses.** Each muscle is supplied by a small nerve branching off from the larger nerve-trunks issuing through the intervertebral foramina The gastrocnemius is supplied by a branch of the sciatic nerve or the nerve of the hind-limb This can be seen entering it very near the proximal end of the muscle Nerve impulses in the living frog come from the nerve centres, but we can stimulate a nerve by pinching it

With a pair of forceps pinch the nerve supplying the gastrocnemius Note that the muscle immediately contracts

Muscles do not die with the death of the animal, but may respond to stimuli for a time after 'death' during which they retain their soft and plaint nature, but after that the myosin of the muscle coagulates and all the voluntary muscles become stiff and hard This condition of the dead muscles is referred to as **rigor mortis** Later on the muscle becomes once again soft on account of the onset of decomposition

90. The Hip-Joint of the Frog.—(Fig. 34) Examine with the

Practical work

help of a lens a section passing through the acetabulum of a tadpole in which the limbs are fully formed. If the section passes through the middle of the acetabulum, it will be seen that the socket is formed partly by the ilium and partly by the cartilaginous pubis Note that the entire socket is lined by cartilage, there being a layer of cartilage even over the portion of the socket formed by the ilium The head of the femur which is rounded and made of cartilage fits into the acetabulum A small chink, however, is left between the two This is known as the **synovial cavity,** lined by a thin membrane forming the walls of the **synovial capsule.** The membrane is closely adherent to the articular surfaces A watery fluid of albuminous nature, called the **synovia,** fills the synovial cavity and serves for the lubrication of the head of the femur in the acetabulum, thereby preventing friction of the one upon the other during movements A strong ligament called the **capsular ligament** closely invests the free portion of the capsule and serves to strengthen the joint and to prevent dislocation In this joint, it will be noted, a wide range of movement is possible The femur, and therefore, the entire hind-limb can move about the acetabulum in any plane

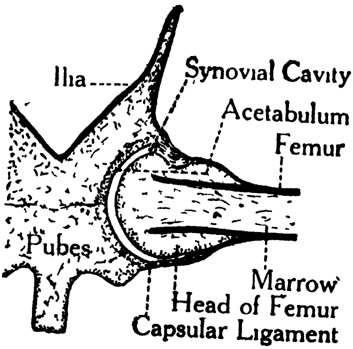

Fig 34 A transverse section through the acetabulum of the frog, illustrating the structure of a ball and socket joint The section passes through plane AB shown in Fig 30, B

(43) Sketch.

91. Kinds of Joints.—There are three main classes of joints in the body of a frog or other vertebrate These are, perfect joints, imperfect joints and immovable joints

(a) **Perfect Joints.**—An example of a perfect joint is furnished by the hip joint, just examined in detail Perfect joints are those that allow of most of the movements of the body In them there are two smooth articular surfaces working against each other and having the lubricating fluid or synovia between. We distinguish various kinds of perfect joints according to the nature of the movements they are capable of. The hip-joint and the shoulder-joint are examples of **ball-and-socket joints** of which one of the articular surfaces is a hollow socket, in which the other, which is a rounded knob, works, allowing movements in all directions In the knee- and elbow-joints, we have examples of **hinge joints** which allow of movements in a single plane only In **gliding joints,** like the ankle and the wrist, the bones slide over each other, the movements allowed by the joint being in all planes, but very limited in extent The gliding joints of the fingers and toes are capable only of movements in a single plane Lastly we get in the higher animals, though not in the frog (e g, 1st and 2nd vertebrae of rabbit) a type of perfect joint known as the **pivot joint.** In this a projection on one bone forms a pivot on which another bone rotates. The movement here again is limited to a single plane.

(b) **Imperfect Joints.**—In this class the adjacent bones are separated by a layer of cartilage and a certain amount of movement of one bone upon the other is made possible by the flexibility of the intervening cartilage. The articulation of the ilium to the ends of the transverse processes of the 9th vertebra and the joints between the centra of the human vertebral column are examples of this type of joint

(c) **Immovable Joints.**—These are merely sutures where two bones are in contact with each other without any intervening cartilage and therefore incapable of movement upon each other In the human skull we get several such sutures or immovable joints, where the bones dove-tail into each other

92. Joints and Movement.—We have seen how the gastrocnemius muscle causes the bending of the shank upon the thigh The bending is made possible on account of the knee-joint which enables the tibio-fibula to move upon the femur In a similar manner all the other movements of the body are caused by muscular contraction and take place about the joints If you imagine for a moment that the entire skeleton was made of one piece without joints, you will readily understand the importance of the joints in the movements of the body. On the other hand, if the skeleton were made of several pieces, without, however, the various parts being definitely articulated together, the contraction of the muscles would merely result in the approximation of the bones to each other Joints give definiteness and precision to the movements of parts of the body thus making the various complex movements of the whole possible Often a particular movement is caused by the concerted action of a number of muscles, acting about a series of joints. In the movement of the hind-limb, for example, the hip joint, the knee, the ankle and the joints of the digits take part, as well as a number of muscles in relation to these joints

The effect of muscular contraction may be merely to cause a relative movement of one part of the body upon the rest, as for example, the head moving on the trunk or the eyes moving in their sockets On the other hand, certain movements may result in the entire body being shifted from place to place This we speak of as locomotion In **locomotion,** some part of the body moves by muscular activity relatively to the substratum, as for example, the sudden extension of the foot about the ankle joint, causing the body to be moved forwards in relation to the ground.

93. Muscular Fatigue.—Continued work of the muscles results in a state of fatigue or exhaustion of the body This condition is brought about by the running down not only of the muscles, but also of the nerve endings or synapses, viz , the places where the processes of one nerve intertwine with those of another (Sect 108) There are two factors which help to induce muscular fatigue, the using up of the energy-producing substance and the accumulation of waste products Lactic acid is formed in muscle during work and it would seem that a primary condition for restoring the muscle to normal is the removal of this waste product by the blood, for which some time is required Hence the value of rest, during which the waste matter is washed out and the energy-producing substance is built up

REVISION QUESTIONS

95 Make a list of the main joints of the human body and classify them

96 What is the flexibility of the vertebral column due to?

97 What are ligaments? What are their functions?

98 Which of the muscles of the human leg correspond to the gastrocnemius of the frog? What are the movements caused by its contraction and which are the joints involved?

99 Why is it that the muscles of a 'killed frog' can contract when stimulated even some time after the killing?

100. Why is it that an earthworm can only perform wriggling movements?

CHAPTER 15

THE NERVOUS SYSTEM—BRAIN AND SPINAL CORD—SPINAL NERVES—CRANIAL NERVES—SYMPATHETIC NERVES—AFFERENT AND EFFERENT NERVES—FUNCTIONS OF THE SPINAL CORD—REFLEX ACTION—FUNCTIONS OF THE BRAIN—FUNCTIONS OF THE SYMPATHETIC NERVES

Material for Study —Frogs killed and their abdomen and back of skull opened and preserved in formaline for two weeks, one for each student, freshly killed frogs, micro-slide of t s spinal cord of the frog, a museum preparation of the cranial nerves of the frog, micro-slide of sympathetic (non-medullated) nerve fibres

94. The Role of the Nervous System.—We have so far studied some of the systems of organs of the frog as if they were separate entities But as a matter of fact, the various organs are interdependent In Chapter 9 we have seen the close relation between the organs of nutrition, respiration, excretion and circulation. The function of each organ or system of organs has to be *controlled*, and the functions of the various systems of organs have to be *co-ordinated*, so as to bring about the well-being of the animal as a whole. In addition to this the entire organism has to work in harmony with its surroundings These functions are performed in the main by the nervous system. "There are many members in the body, yet but one body And the eye cannot say unto the hand, 'I have no need of thee,' nor again the head to the feet, 'I have no need of you' . God hath tempered the body together that there should be no schism in the body" (St Paul)

For convenience of study we divide the nervous system into three parts the central nervous system including the brain and spinal cord, the peripheral nervous system including the cranial and spinal nerves and the sympathetic nervous system.

95. Dissection of the Brain and Spinal Cord.—Frogs previously killed and hardened in formaline may be dissected with advantage Pin the frog with its back upwards. Remove the skin along the dorsal side of the body Note the small **cutaneous nerves** that emerge from the region of the vertebral column and pass into the skin Note also the sub-cutaneous lymph spaces of the dorsal side Remove the muscles of the mid-dorsal region along the entire length of the trunk so as to expose the vertebral column. Between the skull and the atlas (first vertebra)

Practical work

you will note a gap, covered by vascular tissue Remove or cut through this vascular tissue and note the white spinal cord that lies below in the neural canal Now proceed to cut away the neural arches as follows — Insert one point of a pair of strong scissors into the right side of the neural canal and cut the neural arch on that side. Care must be taken to keep the point of the scissors as much as possible in a horizontal position, otherwise the soft nerve cord is likely to be damaged. Now cut the left side in a similar manner, pulling the arch backwards at the same time. When the neural arch is removed the outline of the **nerve cord** (spinal cord) is seen to advantage. Repeat for the remaining neural arches until the whole of the nerve cord is exposed on the dorsal side

Now remove the roof of the skull, beginning where you began exposing the spinal cord, cutting on either side of the foramen magnum The entire fronto-parietal and the upper part of the ring-like sphenethmoid have to be removed The **brain** is now exposed

Note that the posterior end of the nerve cord gradually tapers to a fine point and the terminal portion is inserted into a canal in the urostyle (See Sect 75) Carefully pull out this filamentous terminal portion which is termed the **filum terminale.** Note the **nerve roots** on either side of the spinal cord, especially towards its posterior end From a fancied resemblance to a horse's tail, the filum terminale with the nerve roots on either side of it, is referred to as the **cauda equina.** A thin pigmented membrane called the **pia mater** invests the brain and spinal cord closely (See Fig 37)

Remove the pia mater with the help of fine needles so as to bring out the true outlines of the various parts of the central nervous system, especially the brain

In the region of the third and sixth vertebræ respectively are the **brachial** and **sciatic swellings** of the spinal cord Lying along the entire length dorsally is a narrow, deep groove called the **dorsal fissure.**

Note that the brain and spinal cord are invested in a strong skeletal wall which affords protection to these delicate structures. There is a considerable space between the pia mater and the walls of the cranial cavity and the neural canal, filled by a lymph-like **arachnoid fluid** which protects the organ from shocks, The internal lining of the cranial cavity and the neural canal is formed of a membrane called **dura mater** (Fig. 37). The arachnoid fluid is therefore between the dura mater and the pia mater.

Now proceed to remove the entire brain and spinal cord into a dish or watch-glass as follows — Sever the roots of the spinal nerves as they pass out of the neural canal and lift the spinal cord carefully from the canal Cut away the sides of the cranium so as to expose the right and left sides of the brain fully Gently lift the brain from the cranial floor, beginning at the posterior end and cutting the roots of the cranial nerves one after the other where they pass out of the cranium Remove to the watch-glass and cover with water. Strip away the pia mater from the ventral side Note the **ventral fissure** running longitudinally along the spinal cord

96. Dorsal Aspect of the Brain.—(Fig 35, A) Note the following parts in the dorsal view of the brain beginning from the anterior end (1) **olfactory lobes,** a pair of outgrowths at the anterior-most end (if the dissection has been properly done, the ends of the olfactory nerves or nerves of the nose will be seen to arise from them), the two halves are united mesially (2) **cerebral hemispheres,** a pair of large ovoid bodies immediately behind (1), the two halves of the pair being in contact in the middle line, but not fused. (3) **diencephalon,** behind the hemispheres, a small rhomboid portion marked by a highly vascular patch of the pia mater called the **anterior choroid plexus;** a slender filament arising from the surface of the diencephalon is the **stalk of the** * **pineal body.** Remove the choroid plexus so as to expose the cavity of the diencephalon called the **third ventricle** or **diacoel.** (4) **optic lobes,** a pair of oval bodies immediately behind the diencephalon (5) **cerebellum,** a transverse ridge of nerve matter immediately behind the optic lobes (6) **medulla oblongata,** the hindermost part, broad in front and narrower behind where it passes into the spinal cord; it is covered by a **posterior choroid plexus** upon removal of which the cavity of the medulla oblongata or the **fourth ventricle** is exposed.

(44) Sketch the dorsal view of the brain and spinal cord on the left of the page.

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* The pineal body is connected to its stalk in the larva, but later it is constricted off from the stalk and remains under the skin as the brow-spot of the adult.

97. Ventral Aspect of the Brain.—(Fig. 35, B) Note the olfactory lobes with the olfactory nerves, the cerebral hemispheres, the optic lobes and the medulla oblongata. In addition to these the following structures may be noted. (7) **optic chiasma** or crossing of the roots of the optic nerves, not unlike the arms crossed in front, about the middle of the entire brain, is a girdle of nerve matter arising from the optic lobes, under the chiasma is the floor of the diencephalon (8) **infundibulum,** a heart-shaped portion embraced by the optic chiasma and extending in front of and behind it; it really represents an outgrowth from the floor of the diencephalon, it is superficially divided into two by a shallow groove. (9) **pituitary body** or **hypophysis,** a flat ovoid body attached to the free end of the infundibulum Though in close association with the brain, it is really not a part of it, and can be easily detached. By origin it is a portion nipped off from the gut, and in the adult condition it serves as an endocrine gland (See Sect 417). (10) **crura cerebri,** thick strands of brain matter lying below the optic lobes and partly covered by the pituitary body Note the roots of the cranial nerves arising from the medulla oblongata.

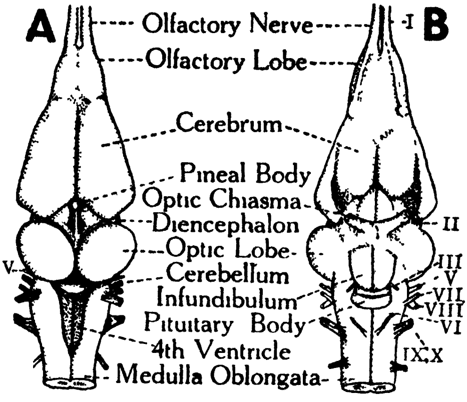

Fig 35 Brain of the frog **A,** dorsal, and **B,** ventral views

(45) Sketch the ventral view of the brain and the spinal cord alongside of the dorsal view.

98. The Cavities or Ventricles of the Brain.—Examine sagittal and horizontal sections of the brain (Fig 36).

You will note that the brain contains a large cavity inside, swelling out into the ventricles in the different portions. This cavity is continued into the spinal cord as a narrow canal. The ventricles are: (1) paired **cerebral ventricles** inside the cerebral hemispheres. They are also called the lateral ventricles or paracoels, they communicate in front with (2) paired **olfactory ventricles** inside the olfactory lobes Posteriorly they are continued into (3) **third ventricle** or **diacoel** inside the diencephalon The passage between each cerebral ventricle and the third ventricle is called the **foramen of Monro.** (3) is a deep narrow channel with a ventral out-pocketing which forms the **cavity of the infundibulum.** (4) **iter** is a narrow passage in the mid-brain or optic lobe region, giving off (5) paired **optic ventricles** into the optic lobes It communicates with the diacoel in front, and behind it expands into (6) the **fourth ventricle** or cavity of the medulla oblongata

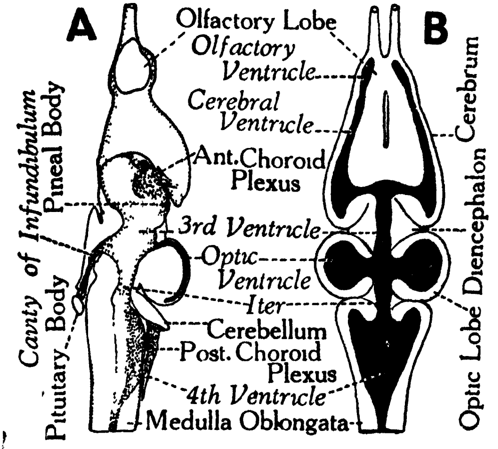

Fig 36 The brain of the frog **A,** sagittal, and **B,** horizontal sections, to show the ventricles of the brain Names of ventricles in italics (B, altered from Ecker)

(46) *Sketch*

99. Transverse Section of the Spinal Cord.—(Fig 36) Examine a prepared section under the low power or the microscope.

Note the **pia mater** investing the entire section In the centre of the section make out the small **central canal** lined by an epithelium The outer region of the section, which is white in the fresh tissue, is termed the **white matter** and the inner core surrounding the central canal is the **grey matter.** The **dorsal** and **ventral fissures** almost divide the section into two symmetrical halves From the **dorsal horn** or dorsal half of the grey matter on each side arise a number of **dorsal roots** of a spinal nerve, and similarly from the **ventral horn** arise a number of **ventral roots** of the same spinal nerve Scattered about in the grey matter are a large number of branching nucleated cells, the **ganglion cells** or **nerve cells** (cf. Sect. 62 (a)) from which the nerve fibres of the ventral roots arise. Note also how the fibres of the grey matter cross from side to side and from the dorsal horn to the ventral.

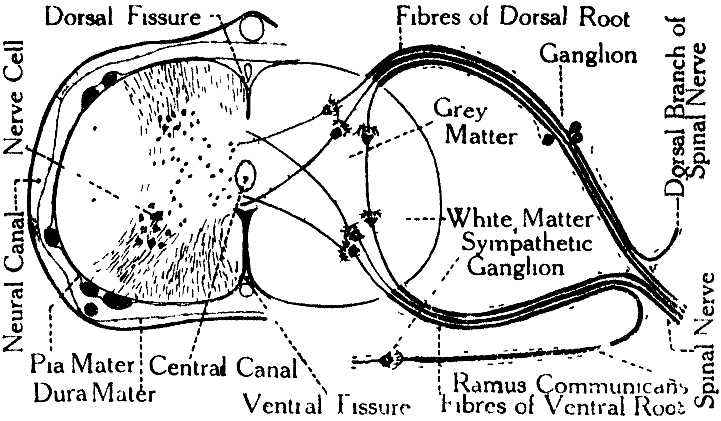

Fig 37 A transverse section of the spinal cord of the frog In the left half are also shown the neural canal, with its membranes, nerve roots and blood vessels The right half shows diagrammatically the paths of the nerve impulses, the nerve centres, the emergence of the dorsal and ventral roots and the formation of the spinal and sympathetic nerves

(47) Sketch

100. White and Grey Matter of the Brain.—The brain is made up of white and gray matter like the spinal cord, but in the cerebral hemispheres, diencephalon and olfactory lobes, the grey matter is external and the white matter internal In the optic lobes and the medulla oblongata, the grey matter forms the layer next outside their respective ventricles just as in the spinal cord

101. Dissection of the Spinal Nerves.—(Fig 38) Examine a mounted skeleton of the frog and note the position of the nine pairs of intervertebral foramina through which the first nine pairs of spinal nerves emerge and the pair of small foramina on the sides of the urostyle through which the 10th pair of spinal nerves emerge from the neural canal (See Sect 75)

Pin down a freshly killed frog on its back and remove the internal viscera, except the dorsal aorta, systemic arches and the coeliaco mesenteric artery Make out the ten pairs of spinal nerves lying between the bodywall and somatopleure or peritonium lining the bodywall. Note that each nerve gives off as it emerges from the vertebral column a large **ventral branch**

Practical work

and a small **dorsal branch** (See Fig. 37) The latter immediately passes into the dorsal muscles and the skin (cutaneous nerve, Sect. 95), while the former supplies either the limbs or the ventral muscles as the case may be Note in particular the following nerves .—

Hypoglossal, the 1st spinal nerve, leaving the neural canal through the intervertebral foramen 1/2 on each side. It passes forwards into the floor of the mouth and innervates the tongue

The **brachial plexus,** formed of the 2nd and 3rd spinal nerves, passes out through foramina 2/3 and 3/4 and issues into the arm A little distance from the vertebral column, the two nerves of each side unite to form an anastomosis or plexus, after which they again separate out Trace the nerves further into the fingers

The 4th, 5th and 6th pairs of nerves are very small and innervate the bodywall.

The **sciatic plexus** formed of the 7th, 8th, 9th and 10th spinal nerves on each side is a large anastomosis from which the nerves of the hind-limbs are given off The first three of these leave the vertebral column through foramina 7/8, 8/9 and 9/urostyle The 10th nerve is very small and issues out through a small foramen on each side of the urostyle, a little distance from its anterior end The main nerves of the plexus pass into the hind limbs, but smaller ones are given to the large intestine, oviducts, urinary bladder, cloaca, etc.

102. Dissection of the Spinal Nerve Roots.—Dissolve out the white calcareous deposits on either side of the centra of the vertebrae, called the **periganglionic glands** or **glands of Swammerdam** Cut away the centra by means of strong scissors severing each from its neural arch alternately on the two sides Take care lest the spinal cord is injured Trace some of the spinal nerves, e g , the 2nd, 7th, 8th and 9th, to their orgin in the spinal cord.

Practical work

Note that each spinal nerve is formed by the union of two roots, a **dorsal root** and a **ventral root** arising from the spinal cord and lying in the neural canal (Fig 37) The roots of the 2nd nerve are very short and pass out at right angles to the cord, while those of the sciatic plexus are very long and pass out from the neural canal at a level considerably behind their origin The latter lie on either side of the filum terminale to form the cauda equina. On each dorsal root near the point where it meets the ventral root to form the nerve trunk is a **ganglion** or small swelling, covered ventrally by the periganglionic gland

(48). *Sketch the spinal nerves and roots dissected*

103. The Cranial Nerves.—Examine a well-dissected museum preparation of the cranial nerves of a frog In Section 95, we have noted the roots of the cranial nerves arising from the ventral aspect of the brain Identify the various cranial nerves, their origin and distribution with the help of the tabular statement below

TABLE 4

TABULAR STATEMENT OF THE CRANIAL NERVES

SERIAL NO	NAME	ORIGIN	DISTRIBUTION
I	Olfactory	Olfactory lobe	Nasal or Olfactory organ
II	Optic	Optic lobe	Eyes, some of the fibres of right nerve cross to left side and *vice versa* to form optic chiasma
III	Occulo-motor	Crura cerebri	Eye muscles
IV	Pathetic	Between Optic lobes and Cerebellum	Eye muscles
V	Trigeminal	Side of Medulla oblongata	Skin of snout, Upper jaw, Lower jaw (A large nerve with three main branches)
VI	Abducens	Ventral side of Medulla	Eye muscles (A small nerve)
VII	Facial	Side of Medulla (same as for V)	Palate, Tympanic membrane, skin and muscles of Lower Jaw
VIII	Auditory	Medulla	Ear, very short nerve
IX	Glosso-pharyngeal	Medulla	Tongue and pharynx
X	Vagus or Pneumo-gastric	Same as for IX	Larynx, Stomach, Lungs, Heart, etc (A large nerve with several branches)

Note that the larger of the cranial nerves, viz, V, VII, IX and X have ganglionic developments where their roots unite to form the nerve trunk. The roots of the fifth and seventh nerves unite in the otherwise irritated, the animal will show signs of pain; while if the other end is similarly treated, there is no response of any kind. The inference is that the root is concerned with the transmission of impulses from the periphery to the spinal cord. By cutting the ventral root of another nerve in a similar manner, it will be seen that the part of the body supplied by the fibres of the root loses all power of voluntary movement and becomes flaccid and paralysed Sensation will, however, remain unimpaired If the cut end nearer the cord is irritated, nothing happens, but if the other end is irritated muscular contractions are produced, showing that the fibres arising from the ventral horns of the grey matter are concerned with the transmission of impulses from the spinal cord to the periphery

Afferent fibres have their peripheral terminations in the sense organs which receive stimuli from the external world. Their function is to transmit these sensory stimuli in the form of nerve impulses to the central nervous system, and hence they are called also **sensory** nerve fibres The efferent fibres, on the other hand, have their peripheral terminations in the muscles and glands of the body to which they carry impulses from the central nervous system Accordingly, they are either **motor** or **secretory.** Efferent fibres distributed to unstripped muscles may be either **accelerators** or **inhibitors** according as the impulses they carry result in an increased or decreased activity of those muscles

107. Functions of the Spinal Cord.—When a sense organ is stimulated by an external stimulus (e g, the skin by touch) the nerve impulse originating in the sense organ travels up one or more of the afferent fibres and reaches the spinal cord by way of the dorsal root of the nerve concerned Directly the stimulus is received on the skin, some muscular contraction takes place, resulting in some movement of the body This is the reaction of the body to the stimulus It means that the impulse which has reached the dorsal horn of the grey matter of the spinal cord has travelled down the ventral horn, the efferent fibres of the ventral root, and the ventral branch of the nerve concerned to the muscle and stimulated it to contract Thus we see that the spinal cord *serves to communicate impulses from a dorsal root to a ventral root*

If the spinal cord is cut at any point of its length, all power of voluntary movement and sensation is lost by those parts supplied by nerves arising from behind the cut. In other words, the means of communication between those parts and the brain has been impaired Hence the spinal cord *serves to conduct afferent and efferent impulses to and from the brain respectively*

If a frog is pithed, that is, its brain severed from the spinal cord by cutting across the medulla, so that impulses can no longer pass from the brain to the spinal cord, it will be seen that the animal loses all power of voluntary movement and remains as if dead, excepting that its heart goes on beating If, however, one of its legs is tickled or irritated with a drop of acid, it draws away the leg or tries to wipe away the acid Since the brain is severed from the cord, it is obvious that the efferent impulses which stimulated the muscles of the leg to contract, so as to cause their movements, could not have originated in the brain The conclusion is that the efferent impulses have originated in the spinal cord itself Hence we see that the spinal cord *serves to originate efferent impulses* independently of the brain.

108. Functions of the Nerve Cells of the Spinal Cord.—In the transverse section of the spinal cord (Fig 36) we have seen that there are groups of nerve cells in the dorsal and in the ventral horns of the grey matter The afferent fibres reaching the spinal cord by way of a dorsal root may be traced to the dorsal horn of the grey matter Each afferent fibre ends there in a **dendron** (See Sect 62 (a)) of protoplasmic processes which branch into fine and yet finer subdivisions The branches of a dendron interlace with those arising from a cell of the dorsal horn Such an interlacing between dendrons is called a **synapse** (See Fig 39) The axons of the nerve cells of the dorsal horns pass ventralwards into the ventral horn, and in their turn form synapses with the nerve cells of that horn The axons of the latter pass out of the spinal cord and form the fibres of the ventral root, ultimately reaching an effector organ like a muscle or gland. Consequently *the function of the cells of the dorsal horn is to receive afferent impulses and transmit them to the cells of the ventral horn. The function of the latter is to originate efferent impulses which pass down the efferent nerve fibres.*

109. Paths taken by Nerve Impulses.—In the preceding section, we have seen one of the paths taken by a nerve impulse reaching the spinal cord, viz., from the dorsal root of a nerve to the ventral root of the same nerve. This is the simplest path that a nerve impulse may take It may, however, pass anteriorwards to the nerve centres of the brain, along the fibres of the white matter of the dorsal side of the cord, returning thence along the fibres of the white matter of the ventral side and ultimately reaching a nerve cell of the ventral horn. Or again, an afferent impulse reaching the dorsal horn may cross over to the other side of the cord where it may cause the cells of the ventral horn to originate an efferent impulse

110. Reflex Action.—We have seen above (Sect 108) that the spinal cord is capable of originating efferent impulses independently of the brain This faculty of the spinal cord accounts for a large number of the common activities of a frog or other animal in its every day life, in which deliberation and intelligence do not play a part Such activities are referred to as reflex actions For example, if the leg of a frog is tickled or pricked, it draws away the leg from the source of irritation as if by instinct If the sole of your foot is tickled you draw away the leg instantly, and this will happen even when you are doing something upon which all your attention is concentrated and perhaps without your ever being conscious of the irritation. Now, we have seen that when the spinal cord of a frog is severed from the brain by cutting the medulla oblongata, the animal is still able to draw away its leg or wipe away the acid in order to escape the irritation, and we came to the conclusion that the spinal cord is capable of originating efferent impulses independently of the brain. Reflex actions are, therefore, actions resulting from the conversion of an afferent into an efferent impulse by a nerve centre like the spinal cord without the intervention of the brain.

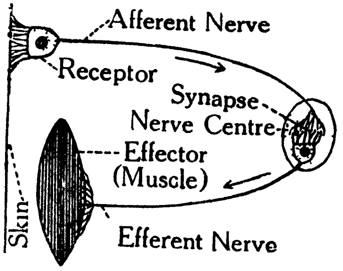

Fig 39 A diagram to illustrate reflex action

111. The Reflex Arc.—(Fig 39) The path along which nerve impulses resulting in a reflex action travel constitutes the reflex arc or the reflex path. A stimulus received by a sense organ or **receptor organ,** e.g., the skin, travels up an **afferent nerve** in the form of an afferent impulse and reaches a **nerve centre** in the spinal cord or brain where a fresh nerve impulse is originated and sent down an **efferent** nerve in the form of an efferent impulse and finally reaches an **effector** organ like a muscle or a gland which is stimulated to activity This series of organs included in the reflex path constitutes the **reflex chain.**

112. The Importance of Reflex Actions.—A large number of the movements of our body are performed as reflex actions A strong light held in front of the eye makes it shut If our hand comes in contact with a hot or cold object we draw the hand away as if by instinct The report of a gun startles us If we see a coin on the road, we stoop and pick it up before we know what we have done The vital functions of the important organs of the body also are reflex actions The action of the gastric glands when food reaches the stomach and the action of the respiratory muscles are two examples In the latter, the irritation of the sensory nerves concerned is due to an imperfectly aerated condition of the blood In other words, the respiratory centres exhibit a specific irritability for carbon-dioxide and are very sensitive to variations in the amount of this gas present in the blood The stimulation of the sensory nerve in this case reaches the medulla and travelling down the cord reaches the motor nerves which enervate the intercostal muscles, diaphragm, etc Walking, reading, writing, etc , which in the child are deliberate voluntary actions, become reflex with practice

From what has been said in the previous sections, it is not to be understood that the spinal cord alone contains the nerve centres for reflex actions Reflex centres are present in the grey matter of the brain as well , and the receptor organ may be any one of the sense organs placed in the head and connected directly to the brain by afferent fibres A stimulus received by one of these receptors may produce a reflex action in any part of the body supplied by the efferent nerves from the spinal cord Conversely, a stimulus received by a receptor organ supplied by afferent fibres from the spinal cord may produce a reflex action in an effector organ situated in the head. This is made possible by the fact that nerve fibres running in the white matter connect the nerve centres of the spinal cord with those of the brain.

113. Functions of the Brain.—The functions of the brain and its various parts are determined by removing the brain or its parts and observing the behaviour of the animals thus experimented upon As we have seen above, if the entire brain is removed, the animal· loses all power of voluntary action and can perform only reflex actions The faculty of associative memory is lost as the result of removal of the cerebral hemispheres If the diencephalon as well as the cerebral hemispheres is removed complete loss of spontaneous movements results "The optic lobes exercise an inhibiting influence on the reflex activity of the spinal cord Removal of the optic lobes results in an increased irritability of the spinal cord, while stimulation of the optic lobes may greatly check the spinal reflexes" (Holmes) The power of co-ordinating the movements concerned with locomotion is lost when the cerebellum is extirpated The medulla oblongata is the seat of nerve centres most essential for the maintenance of life, such as respiration, circulation, snapping at food, swallowing, etc

114. The Functions of the Sympathetic System.—We have seen above that the sympathetic system supplies nerves to the heart, blood vessels and the internal viscera generally in addition to the nerves from the central nervous system Thus, the heart, for example, receives a branch from the vagus (Sect 103) and one from the sympathetic (Sect 104) If the heart of the freshly killed frog is removed from the body, it will still continue to beat, showing thereby that the normal working of the heart is independent of the nervous system The nerves of the heart, then, are not for originating the impulses which result in the contractions of the heart, but for accelerating or retarding the activity of that organ under differing circumstances If the branch of the vagus supplying the heart is stimulated, the rate of heart-beat slows down, and a sufficiently strong impulse will cause the stopping of the heart in the dilated condition On the other hand, the stimulation of the sympathetic nerve of the heart accelerates the rate of heart beat

In a similar manner, the degree of contraction or dilation of the blood vessels is regulated by the **vaso-motor nerves** arising from the sympathetic system. Normally the arteries are in a state of slight contraction as the result of a constant flow of impulses from the vaso-motor centre in the medulla oblongata along the vaso-motor nerves. When it becomes necessary to dilate the blood vessels, so that a larger quantity of blood may flow through them in any part of the body, the intensity of these impulses is reduced, resulting in the relaxation of their muscular walls.

Several of the glands of the body react to the stimuli received by the arteries which supply them with blood by an increased or decreased rate of secretion The dilation of the arteries and consequent enhanced supply of blood accelerates secretion, while their constriction has the opposite effect For instance, when food enters the stomach, certain afferent impulses pass along the gastric nerves to the central nervous system, which answers back by reducing the intensity of the efferent impulses along the vaso-motor nerves supplying the gastric arteries, causing their dilation and consequent increased secretion of gastric juice.

REVISION QUESTIONS

101. Construct the diagram of a transverse section passing through the vertebral column, (1) intervertebrally and (2) vertebrally, and mark in them the following —spinal cord, central canal, white matter, grey matter, pia mater, dura mater, arachnoid fluid, dorsal root, ventral root, ganglion of dorsal root, spinal nerve trunk, ramus communicans, parts of the vertebra

102. Trace the path of the nerve impulses leading to each of the following actions of a frog —1 Snapping at a fly, 2 Jumping into water on the approach of danger, 3 Drawing the nictitating membrane over the eye when poked, 4 Springing with the ejection of urine when disturbeed from behind

103. How are the brain and spinal cord protected from external injuries ?

104 The central canal inside the spinal cord and the ventricles of the brain are spaces which were once a part of the outside world (See Section 150) What does this signify ?

105 Describe an experiment to show that the spinal cord contains nerve centres

106 Explain why if a frog's back is broken it cannot move its legs voluntarily, but they may move involuntarily when tickled

107 What is the function of the ganglia of the dorsal roots of the spinal nerves?

108 Which of the cranial nerves are purely sensory and which are the senses involved ?

109 Why is it more correct to use the terms 'afferent' and 'efferent' as applied to nerves than 'sensory' and 'motor' ?

110 Which are the nerves supplying the internal viscera and the blood vessels ? Mention which of them are sensory motor, secretory, inhibitory, etc

CHAPTER 16

SENSE ORGANS—ORGANS OF TOUCH, TASTE AND SMELL—THE EYE—THE EAR—MEMBRANOUS LABYRINTH—HEARING—EQUILIBRATION

Material for Study A few killed frogs, microslides of section of eye of frog through optical axis and of t s advanced tadpole through the ear region

115. The Role of the Sense Organs.—In the previous chapter we have tried to see how the various systems of organs of the frog are controlled and their activities co-ordinated to ensure the welfare of the animal as a whole It will be readily understood that the activities of the various organs within the body are related to whatever is without the body or its **environment.** The main factors that form the environment are the surrounding topography and the presence or absence of food, light, heat, enemies, etc. Now all these factors are variable in time and in space and every changing condition requires an adjustment in the organism calculated to counteract or benefit by the change The organs of special sense, viz, touch, taste, smell, sight and hearing, enable the organism to perceive these changes in the environment, so that suitable internal adjustments in the organism may be made These are the media through which stimuli from the outer world are received, and the impulses caused by the stimuli are passed on to the afferent nerves, which in their turn transmit them to the central nervous system

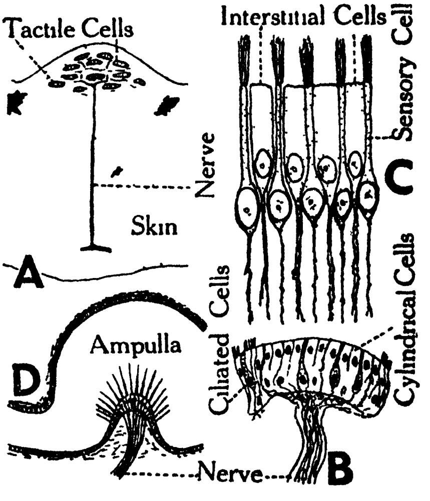

Fig 40 **A**, a tactile corpuscle as seen in a vertical section of the skin, **B**, a vertical section through a fungiform papilla, **C**, portion of olfactory epithelium; **D**, section through an ampulla of the membranous labyrinth, with the acoustic spot and auditory hairs

116. The Sense of Touch.—The whole of the skin is an organ of touch or a tactile organ In specially prepared sections of the skin we can make out under the microscope groups of large flattened cells called the **tactile cells.** The fine terminations of the afferent nerve fibres of the skin supply these cells. A group of such cells may be said to form a **touch corpuscle** (Fig 40, A). The touch corpuscles are alone the sensitive portion of the skin, but since they are distributed all over the skin, the entire skin is sensitive to touch. The touch corpuscles are covered over and protected by the epithelial cells of the epidermis, so that normally the stimuli which result in the sensation of touch are not directly applied to the corpuscles When this happens, as for example, when the skin is cut and the corpuscles are exposed, the sensation is not one of touch, but of pain

The skin is also sensitive to warmth, chemical agents and humidity of the air, and, it is said, is also influenced by the intensity of light.

117. The Sense of Taste.— Scattered all over the mucous membrane of the mouth, but particularily abundant on the tongue and the floor and roof of the mouth are **taste buds** which are concerned with the sense of taste. On the tongue there are small mushroom-shaped papillae called the **fungiform papillae** (Fig 40, B), with their free ends broader than their bases The surface of their free ends is covered by cylindrical ciliated epithelial cells, between which are scattered various forms of elongated cells connected at their base with fibres of the gustatory nerves Direct contact of food substances with these cells supply the stimulus which, passing up the afferent fibres of the palatine and glossopharyngeal nerves and reaching the brain, results in the perception of taste.

118. The Sense of Smell.—The sense of smell is situated in the **olfactory capsules.** These are a pair of cartilaginous capsules placed between the nasal and vomerine bones (See Sect 72). The nasal cavity is lined by a mucous membrane, the exposed surface of which is formed by an epithelium of columnar cells interspersed with special cells known as the **olfactory cells** (Fig 40, C). These form the essential organs of smell and are very elongated and produced into very fine protoplasmic processes, not unlike a microscopic painting brush. The deeper ends of these olfactory cells are connected with the fibres of the olfactory nerves As in the case of taste, so in the case of smell also, the stimuli which result in the perception of smell are produced by the direct contact of extremely minute particles given off into the air from any odoriferous substance

119. The Structure of the Eye.—Remove the eye from a freshly killed frog, cut away the eye-muscles clean and note the rounded shape of the eye-ball. The outer coat of the ball which makes it firm is the **sclerotic,** a cartilaginous capsule. The outer end of the eye ball opposite where the **optic nerve** enters is transparent and is distinguished as the **cornea.** Through it you can see the **iris** as a dark pigmented ring surrounding the **pupil** or aperture of the eye It is through the pupil that light enters the eye.

Practical work

Now, examine a section of the eye passing through the optical axis (Fig 41) under the low power of the microscope or a strong lens Note the following —the crystalline **lens,** placed within the cavity of the eye-ball, is almost round in the frog, while in the higher vertebrates it is biconvex Between the lens and the cornea is a space or **anterior chamber** containing a watery fluid, the **aqueous humour** Behind the lens is another and larger space called the **posterior chamber** filled with a gelatinous fluid, the **vitreous humour.** Next inside the sclerotic is a vascular pigmented layer, the **choroid;** and innermost comes the **retina** made up of an outer pigment layer and an inner nervous layer lining the posterior chamber and forming the sensitive part of the eye

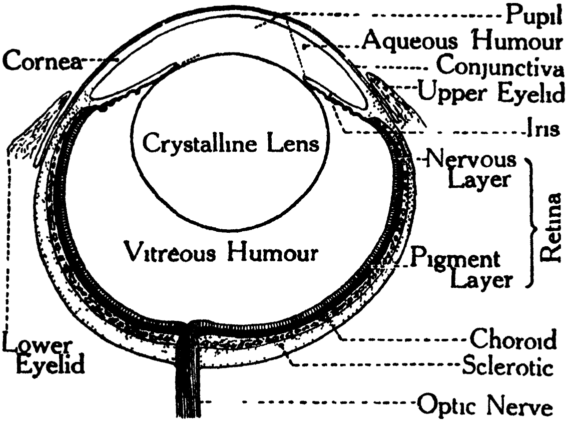

Fig 41 A vertical section of the eye of the frog through the optical axis

Open the eye under water with a pair of scissors and make out the parts, noting particularly the transparent lens and the dark interior of the eye-ball.

(51) Sketch the section through the optical axis of the eye

120. Vision.—The sensitive part of the eye is the retina which is provided with the fibres of the optic nerve. In seeing, the image of the object seen is caught on the retina very much in the same way the image falls on the sensitive plate of a camera Light entering the eye at the cornea and through the pupil is refracted by the lens and all the rays converge towards a small portion of the retina lying in the optical axis of the eye, and form a reduced and inverted image of the object seen The light-stimuli received by the retina are passed on along the fibres of the optic nerves, and ultimately reaching the brain results in vision (For a fuller account see Sect. 440)

121. Movements of the Eye.—The eye can be directed towards any object, within limits, by the action of the four **recti** muscles, anterior, posterior, superior and inferior The thrusting out of the eye is effected by the **levator bulbi** and its withdrawal into the socket by the **retractor bulbi.** Two **oblique** muscles, superior and inferior, enable the eye to be rotated on its optical axis.

122. The Structure of the Ear.—(Fig 42) Examine a prepared transverse section of the hinder region of the head of an advanced

Practical work

tadpole or young frog, passing through the two tympanic membranes. Note the following.—The **tympanic membrane** (level with the skin of which it is a modified portion), stretched on a ring-like cartilage, the **annulus tympanicus,** cut in two places in the section Internal to the membrane is a large space, the **tympanic cavity,** across which lies an elongated bony rod called the **columella** suspended between the membrane and the inner wall of the tympanic cavity From the inner side of its floor the tympanic cavity is continued as the **Eustachian canal** into the mouth (See Sect 10) A little above where the Eustachian canal begins is a small plug of cartilage called

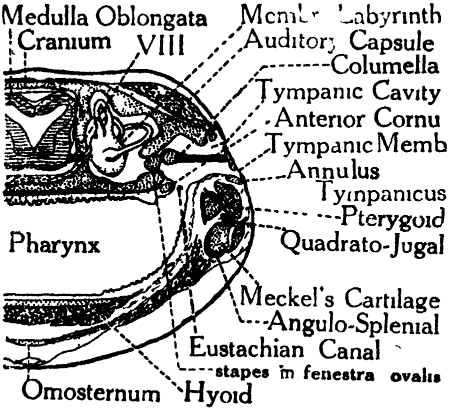

Fig 42 A transverse section across the head through the ear of the frog, incomplete on the left side Cartilage, dotted, bones, dark, muscles, speckled, brain, striped Note the lymph spaces just under the skin

the **stapes** fitting into an aperture called the **fenestra ovalis.** This opening leads into a large cavity having a strong cartilaginous wall, the auditory capsule (See Sect 72). This cavity, in the living frog, is filled with a watery fluid called perilymph A complicated organ called the **membranous labyrinth** floating in the perilymph takes up most of the space in the auditory capsule The auditory nerve (VIII) issuing from the medulla oblongata can also be seen entering the membranous labyrinth

(52) Sketch

123. The Membranous Labyrinth.—Only portions of the organ can be seen in sections. Fig 43 may be studied carefully in order to gain an idea of its structure It consists of a membranous sac divided by a deep constriction into a dorsal portion called the **utriculus** and a ventral portion called the **sacculus.** The latter has a small posterior outgrowth called the **cochlea.** Three **semicircular canals,** each opening into the utriculus at either end, are very characteristic They also have membranous walls like the utriculus and sacculus From their peculiar position in three planes, each at right angles to the others, they may be respectively called the anterior vertical, the posterior vertical and the horizontal canals The vertical canals meet each other at their near ends before opening into the sacculus Each of the semicircular canals has got a dilated bulb or **ampulla** at one end The utriculus, sacculus and the canals are filled with a fluid, the **endolymph,** in which minute calcareous particles or **otoliths** are present From the inner side of the sacculus arises a tubular outgrowth, the **ductus endolymphaticus,** not seen in the figure, which extends dorsally, where it curves inwards and penetrates the cranial wall, and entering the cranial cavity forms a large sac, the **saccus endolymphaticus.**

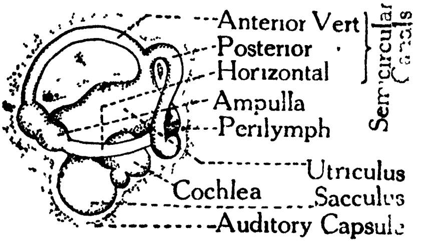

Fig 43 Lateral view of the left membranous labyrinth inside the auditory capsule The ductus and saccus endolymphatics are hidden from view

There is an epithelium of cubical cells lining the entire organ. In the ampullæ and other parts of the organ where the branches of the auditory nerve enter, the epithelial cells are elongated and bear very fine protoplasmic processes called **auditory hairs** (Fig 40, D). Each such region of modified cells is called an **acoustic spot,** and is supplied with the fibres of the auditory nerve.

124. Hearing and Equilibration.—Both these functions are performed by the membranous labyrinth In hearing, the sound waves impinge on the tympanic membrane and the vibrations set up in this are communicated along the columella to the stapes and thence to the perilymph Through this liquid medium the vibrations ultimately reach the membranous labyrinth and the endolymph contained therein. In this manner the auditory hairs of the acoustic spots of the sacculus are stimulated and gives rise to the sensation of sound.

That the membranous labyrinth is concerned also with the maintenance of equilibrium is shown by experiments with frogs in which one or both labyrinths or even one or more semicircular canals of one or both sides are injured. Removal of the labyrinth on one or both sides makes the frog incapable of maintaining an upright position. Injury to one of the horizontal canals makes the frog move in a circle, while injury to the vertical canals causes abnormal movements in a vertical direction In this connection it is highly significant that the semicircular canals are placed in three planes mutually at right angles, enabling the endolymph pressure to be resolved into three components which can be separately appreciated by the brain A sideways tilting of the body would throw an increased pressure of endolymph on the lateral, i e, horizontal canal of that side and a reduced pressure on that of the other side The disturbances set up in the endolymph would be communicated to the sensory processes of the ampullæ and so to the brain which would cause a compensatory efferent impulse to be sent out to the muscles concerned with righting the position of the body. Similarly a forward tilting would act on the anterior canals of the two sides, and so forth

REVISION QUESTIONS

111 What are the essential and what the accessory parts in each of the sense organs described above?

112 What is the nature of the nerve fibres which are distributed to the sense organs?

113 All the organs of special sense are in relation to the outside of the body What is the significance of this?

114. What are the possible causes of the loss of any of the senses?

different from chromatin grains They are called **nucleoli** by some, while others consider them to be two different types of structures, viz, nucleolus and **karyosome.**

The nucleus is of profound importance to the cell which cannot remain alive without it It is said to be the controlling centre of the whole cell If a cell is divided into two so that the entire nucleus is in one part, the enucleate part would soon die and disintigrate, while the other will continue to live normally Not only is the nucleus concerned with the nutrition and growth of the cell, but, as we shall presently see, also with the process of cell-division which is primarily a process of equitable division of the nucleus between the resulting daughter-cells.

134. Mitosis.—This is the name given to the complex processes involved in the division of the nucleus leading to the division of the cell itself Each living cell of the body is capable of growth and division (subject to certain exceptions and limitations) When a cell has reached a certain stage of growth, it divides into two cells Each of these cells grows and divides in its turn By a repetition of this process a large number of cells are produced from a single original cell When a fertilised egg develops into an embryo, it is nothing other than a process of repeated cell-division In other words, beginning with the single celled (fertilised) ovum, a many-celled embryo is formed by repeated mitosis or cell division

A fully grown cell like the one above described is termed a **resting cell** and would soon undergo a process of mitotic division A resting cell contains a resting nucleus (Fig 46, 1) The following changes which fall into four phases, prophase, metaphase, anaphase and telophase, take place in the cell during mitosis

The **prophase** (Fig 46, 2, 3, 4) is intitated by the formation of fine radiating strands of protoplasm around the centrosome, which has already divided into two, giving rise to two star shaped figures in the astrosphere The isolated chromatin granules of the resting cell gather in a long coiled thread or **spireme** which soon gets broken into a number of short rods called **chromosomes.** In the frog there are 24 chromosomes in all the cells of the body except in the germ cells which contain only half that number The same principle holds good for other animals and plants as well, viz, each species has a definite number of chromosomes in its body cells and its germ cells contain only half that number The two centrosomes with the astral figure move furthur apart and occupy opposite ends of the nucleus, the cytoplasmic threads between them forming a spindle-like figure. The nuclear membrane gradually disappears The chromosomes get arranged in the equatorial plane of the spindle (of which the poles are marked by the centrosomes) in the form of a ring.

During the **metaphase,** (Fig 46, 4) each chromosome splits longitudinally into two, giving rise to two rings of chromosomes, one on each side of the equatorial plane

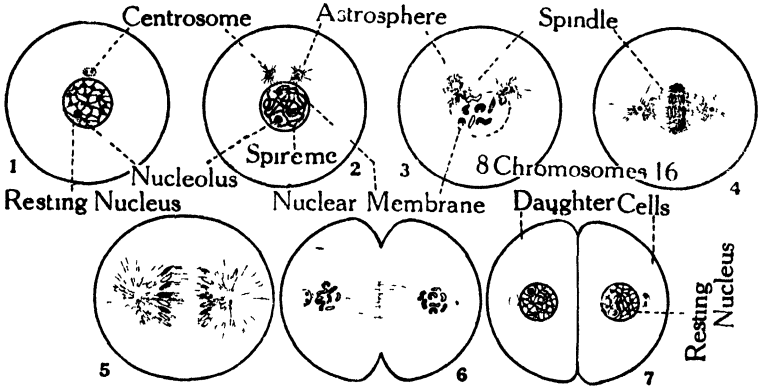

Fig 46 Diagrams showing the progress of mitosis (Altered from Wilson) **1**, resting cell, **2—3**, prophase, **4**, metaphase, **5—6**, anaphase, **7**, telophase

During the **anaphase** (Fig 46, 5, 6) each circlet of daughter chromosomes is drawn towards' the nearest centrosome along the threads of the spindle, as if attracted towards it, until ultimately they gather at the poles A superficial groove appears in the cytoplasm along the equator of the cell.,

In the last phase of mitosis called **telophase** (Fig. 46, 7) the chromosomes of each group become reduced to grains of chromatin, like those of the resting cell and a nuclear membrane appears around each, thus building up two resting nuclei The superficial groove deepens and cuts the entire cell into two daughter cells.

135. Amitosis.—In diseased and worn out cells mitotic division does not take, but only amitotic or direct cell division In this process the nucleus elongates and becomes dumb-bell shaped and eventually snaps into two The cytoplasm follows suit and two cells are formed

136. Chromosome Number.—We have seen above that the number of chromosomes in the cells of the frog is twenty-four. Every species of animal has its own chromosome-number An example of an animal with a small chromosome-number is furnished by the round worm of the horse, *Ascaris megalocephala* Its cells possess only four chromosomes each At first sight one may conclude that when an egg and a sperm of any particular species unite in fertilisation the resulting zygote will have double the number of chromosomes characteristic of the species (4+4=8, in *Ascaris*) and that in the next generation the number would be 8+8=16 and so on, increasing in geometrical proportion every generation As a matter of fact this does not happen, for *each germ cell has only half the number of chromosomes* characteristic of the species This halving of the chromosome-number takes place during the process of formation of germ cells or gametes in the parent body known as gametogenesis

137. Gametogenesis.—The gonads are, like other organs, made up of a large number of cells including those of the germinal epithelium (Sect 126 and 128) It is from the latter that sperms or eggs are produced by cell-division These primordial cells of the germinal epithelium are called **gametogonia** (spermatogonia in the male and oogonia in the female) When sperms or eggs are about to be produced the gametogonia divide by active repeated mitotic divisions (Fig 47, A) and give rise to a large number of **gametocytes** (spermatocytes in the male and oocytes in the female) Two more successive divisions of the gametocytes would result in the formation of sperms (spermatogenesis in the male) or of eggs or ova (oogenesis in the female). It is during the first of these two divisions that the reduction of the chromosome number takes place Hence that division is distinguished from all other cell divisions as reducing division or **meiosis.** ✓

138. Spermatogenesis.—(Fig 47, B) Each male gametocyte or spermatocyte grows somewhat in size. Its chromosomes are re-formed from the chromatin grains. In the horse-worm in which the chromosome-number is four, close microscopic examination at this stage shows that these four are actually of two types, the two of each type being similar in size and shape For convenience, let us denote the two chromosomes of one type by the letters I, **I** and the other type by J, **J**. During the meiotic or reducing division, like chromosomes get closely applied to each other (synapsis), thus forming two pairs I **I** and J **J** The resulting daughter cells receive each one I type and one J-type of chromosome. It will be noted that here the longitudinal splitting of each chromosome so characteristic of the end of prophase in mitosis is entirely absent and each chromosome passes *in toto* to the daughter cells or **secondary gametocytes.**

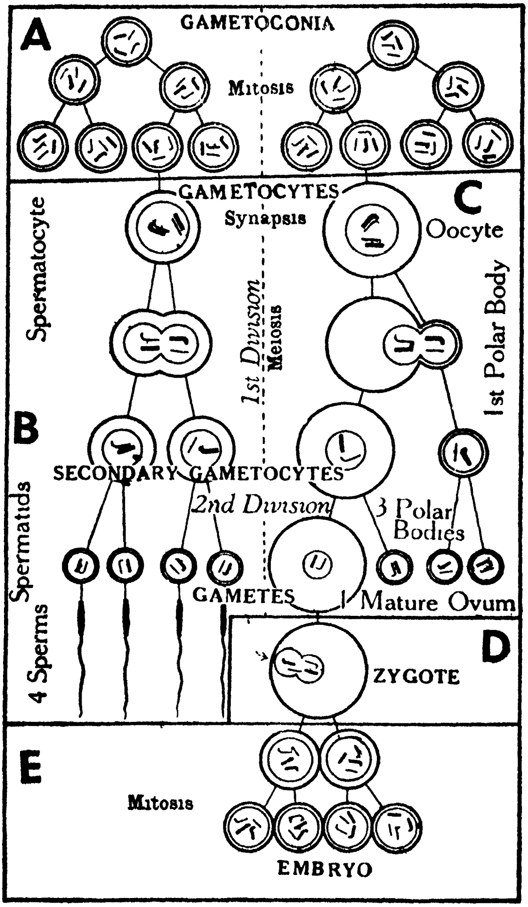

Fig 47 Diagrams illustrating the phases of sexual reproduction, from the gametogonia to the embryo **A** the gametogonia give rise to gametocytes by mitosis, **B**, spermatogenesis **C**, oogenesis, **D**, syngamy or fertilisation, **E**, segmentation of the zygote to form the embryo

Without entering upon a resting stage as in mitosis, each secondary gametocyte proceeds forthwith to undergo a second division resulting in four cells called **spermatids** each with one chromosome of the I type and one of the J type The nucleus of each is re-formed from the chromosomes and each acquires a long protoplasmic tail, thus becoming a **sperm** or spermatozoon. One spermatocyte thus gives rise to four sperms, each capable of fertilising an ovum.

139. Oogenesis.—(Fig 47, C) The corresponding process in the female, viz , oogenesis or maturation of the ovum is similar in all essential respects to spermatogenesis It is sufficient, therefore, to note here only the important differences between the two

The oocyte grows enormously in size by the increase of its cytoplasm and often by the deposition of yolk-granules In the meiotic division that ensues instead of forming two daughter-cells of equal size we get one large cell or **secondary oocyte** and one very small cell or **first polar body** (Sect 130) Each contains two chromosomes only. Both divide again without a resting stage, the secondary oocyte giving rise to one **mature ovum** and a **second polar body**, while the first polar body divides into two smaller polar bodies Out of one oocyte, then, comes one mature ovum and three polar bodies, four cells in all, as in the corresponding stage in spermatogenesis Only the mature ovum, however, is capable of being fertilised by a sperm, the polar bodies dying and disintegrating sooner or later

140. The Ovum of the Frog.—(Fig 48, B) Procure some ova from the abdomen of a freshly killed frog and also some from freshly laid spawn The unlaid egg will be seen to be smaller in diameter than the eggs from the spawn. This is due to the fact that the jelly swells up with water immediately after laying and becomes very thick The size of the cell itself, however, is not affected Note that each egg has a dark upper pole called the **animal pole** and a white lower or **vegetal pole.** The vegetal pole is devoid of pigment and contains a large mass of yolk, while the dark pole in addition to the black pigment has more protoplasm in it and carries the nucleus. Each cell is covered by a very thin non-cellular vitelline membrane and outside this is the gelatinous coat.

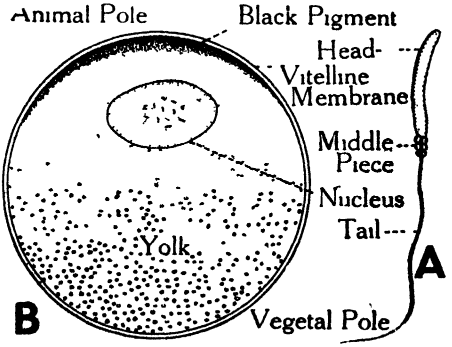

Fig 48 Germ Cells of the Frog **A,** a sperm, (X 1000) , **B,** an ovum, (X 12). (B, altered from Morgan)

(55) Sketch.

141. The Sperm of the Frog.—(Fig 46, A) While in the seminal vesicle, the sperms float in an albuminous fluid This spermatic fluid, when examined under the microscope, is seen to contain very large numbers of sperms. Each sperm is a highly modified cell

Take a small drop of seminal fluid from the seminal vesicle of a freshly killed frog and place it on a clean slide in normal saline, put a cover-glass and examine under the high power Note the teeming numbers of sperms swimming about in the fluid. Note the **head,** and the **tail** by the lashing movements of which the sperm is able to swim about The head consists of a large nucleus covered by a thin film of protoplasm

The tail is entirely made of protoplasm When examined after proper staining the nucleus becomes clear and a peculiar structure called the **middle piece** also comes into view The middle piece is situated at the junction of the head and the tail.

(56) Sketch

TABLE 5

142 THE EGG AND SPERM OF THE FROG COMPARED

	EGG	SPERM
Size	Large, 1/8 inch diameter	Small, 1/1000 inch long
Nucleus	12 chromosomes	12 chromosomes
Cytoplasm	Large, amount, laden with yolk	Small amount
Behaviour	Passive	Motile, swimming by means of tail
Numbers	Less numerous than sperms	Much more numerous than eggs
Function	Supplies embryo with nutriment Contributes half the number of chromosomes of the zygote	Contributes the other half of the chromosomes of the zygote

143. Fertilisation.— (Fig 47, D) When the female frog spawns the male who is clasping her sheds the spermatic fluid or milt over the mass of eggs. The sperms swim about in water and penetrate the soft jelly-coat of the eggs Each egg is surrounded by several sperms, but one and one only enters the egg and forthwith the tail is dropped, and the nucleus of the head of the sperm penetrates deeper and deeper into the cytoplasm The trail of the **male pronucleus** (as the sperm nucleus is now called) can be made out by a line of black pigment which it draws along with it into the interior of the egg Under the vitelline membrane of the freshly laid egg is seen the first polar body as a minute globular cell The second polar body is actually budded off after laying and often after the sperm head has penetrated the egg The nucleus of the egg that remains behind after the extrusion of the second polar body is called the **female pronucleus.** The male pronucleus now approaches the female pronucleus, and the middle piece of the sperm which is really its centrosome now comes into view) From the latter a spindle is formed. The two pronuclei resolve into two sets of 12 chromosomes each and come to lie at the equator of the spindle The chromosomes split up into chromatin and a zygote nucleus, in which the nuclear material of the male and female pronuclei is mixed, is formed. The normal number of chromosomes characteristic of the species is thus restored The process of fertilisation or syngamy is complete and the egg is ready for development into an embryo

REVISION QUESTIONS

115 How does meiosis differ from mitosis?

116 What are germ Cells? How do they differ from the other cells of an organism?

117 Construct diagrams similar to Fig 47 to illustrate the gametogenesis of the frog

118 What is the significance of the terms, Reduction division and Maturation?

119 Clearly define the terms, gametocyte, secondary gametocyte, gamete, oocyte, ovum, spermatocyte, sperm, zygote

120 What do you understand by the terms, chromosome, chromatin, cytoplasm, protoplasm, nucleus

121 What are the various kinds of cells you have examined under the microscope so far?

122 What is the relation between division (multiplication) of cells and growth of tissues or of the body?

123 How does a complex organism like the frog arise from a comparatively simple structure like the fertilised ovum or zygote?

124 How does the frog's egg differ from the hen's egg?

125 What are the various kinds of tissues that enter into the formation of the testis and the ovary of the frog?

126 What are the secondary sexual characters of the frog, of the fowl?

127. What are the uses of the yolk, black pigment and jelly to the egg?

128. What purpose is served by the protoplasmic tail of the sperm ?

129 Is the coelomic cavity of the frog entirely closed, or does it open to the outside ?

130 What is the breeding period of the frog in your part of the country ? What, if any, are the factors that determine the period ?

131. A frog lays thousands of eggs in a season Is the rate of increase of frogs proportionate to this vast output ? If not, why ?

CHAPTER 18

REPRODUCTION (Contd)—SEGMENTATION—GASTRULATION—THE THREE GERMINAL LAYERS—THEIR DERIVATIVES—THE NERVE CORD—THE NOTOCHORD—THE COELOM—PROCTODAEUM AND STOMODAEUM—THE TADPOLE—ITS METAMORPHOSIS

Material for Study Procure freshly laid spawn of a frog or the strings of eggs of a toad and place them in water in an open aquarium jar Separate out a portion of the spawn and throw it into Bouin's fluid* for a few hours and transfer it to 10 % formaline in a small tube Treat samples of the spawn in a similar manner at the end of every 6 hours up to time of hatching and keep the various stages in different labelled tubes

§ Micro-slides of sagittal sections of blastula and gastrula of the frog

Rear the tadpoles in a balanced aquarium stocked with algae for their food Remove a few tadpoles at intervals of 48 hours until metamorphosis Preserve each stage in a separate tube noting the age on the label

Practical work

144 Segmentation.—Examine the eggs from each tube in order noting the following with the help of a lens the black and white areas and their extent, the grooves on the surface of the egg and the planes in which they lie, the number of cells at each stage seen on the surface and the relative sizes of the cells of the black and white poles

The fertilised egg or **zygote** undergoes mitotic division several times in succession resulting in a large number of cells These cells and all the cells of the frog that would ultimately arise from them contain 24 chromosomes each. As long as the cells thus formed are enclosed by the vitelline membrane of the egg, that is, till the time of hatching of the embryo, there is obviously no means for the embryo to take any food from outside The yolk that is contained in the egg itself serves for food during the embryonic life Thus it is seen that with the progress of development there is a gradual diminution in the amount of yolk contained in the egg. Since the embryo or its cells cannot feed on extraneous matter, they become smaller and smaller as their number becomes larger and larger.

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* For preparing Bouin's fluid, mix 75 parts of saturated aqueous solution of picric acid, 25 parts of strong formaline and 5 parts of glacial acetic acid,

In the earlier stages of segmentation, the cells cal[illegible] **blastomeres** (Fig. 49, A) can be easily made out with the help of a lens, but as they become smaller and smaller it becomes impossible to make them out by mere superficial examination.

The first division of the zygote is seen as a groove which makes its appearance at the animal pole and slowly extends towards the vegetal pole It therefore takes place in a meridional plane. The second division is at right angles to the first, but also meridional and cuts the two half cells into four quarter cells Each of the four has a black portion and a white portion The third division is horizontal and cuts the four quarter cells in the equatorial plane of the egg. Now there are eight cells in two tiers of 4 each, the cells of the upper tier being slightly smaller than the yolk cells below Two divisions now take place simultaneouly bisecting the angles between the first two meridii Now there are altogether 16 cells. Two horizontal divisions, one near the black pole and one below the equator result in 32 cells. Furthur meridional and vertical divisions give rise to 64 cells Henceforth, the divisions are not so regular, but the cells of the black pole divide quicker, while those of the white pole, containing as they do a large amount of yolk (a non-living substance), divide but slowly Thus we find that the dark hemisphere now consists of a large number of small cells, and the white of a fewer

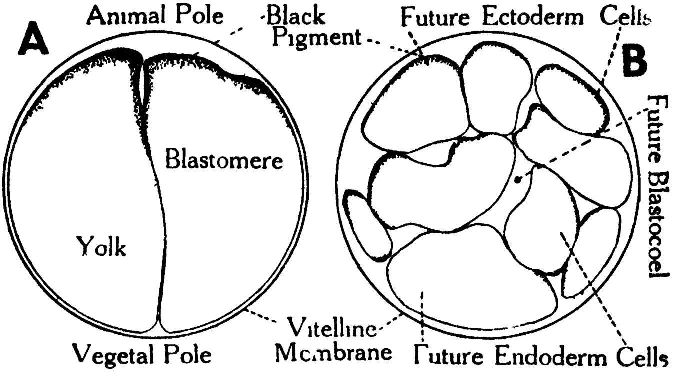

Fig 49 Two sections showing the early cleavage of the zygote of the frog (× 15) **A**, 2 cell stage, **B**, a later stage with several cells, among which the blastocoel is appearing

Note the vitelline membrane which holds the cells together number of larger cells. In the course of further segmentation, however, even the yolk cells become very small and their cell outlines difficult to make out externally.

(57) *Sketch the various stages of segmentation.*

145. Blastula.—If at this stage the embryo is cut into two (Figs. 49, B & 51, A) it will be seen that the interior is not solid, but that a segmentation cavity or **blastocoel** has made its appearance in the animal hemisphere. The embryo is now termed a blastula, which can be defined as a hollow globular mass of cells derived from a single fertilised ovum.

(58) *Sketch the sagittal section of the blastula under the microscope*

146. Gastrula.—The next landmark in the development is the gastrula. On the surface of the embryo, it is seen that the dark cells of the animal pole gradually extend downwards over the white cells of the vegetal pole so as to cover them all over, except a small circular area where the yolk cells still show on the outside called the **yolk-plug.** The growth of the dark cells is not uniform on all sides, but takes place in the manner indicated in Fig 50 in which four successive stages of the embryo, as seen externally, are shown. Fig 50, A shows the completely segmented egg, viz , the blastula and D, the fully formed gastrula In all, v marks the vegetal pole of the unsegmented egg and the white line, the equator By the time segmentation is complete the black area has already extended over the equator and further down over the upper region of the white area (Fig. 50, A). On one side of the em-

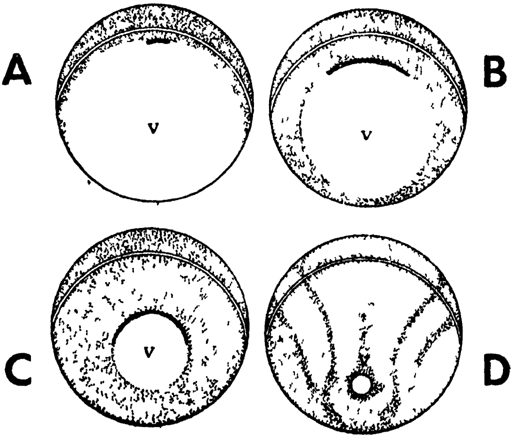

Fig 50 Four diagrams illustrating the manner of overgrowth (epiboly) of the black (pigmented) cells of the animal hemisphere over the yolk cells and the consequent formation of the yolk plug Dotted area shows the pigmented region , the rest, the yolk region , the white line, the equator of the egg and the dark line, the blastopore The neural plates have made their appearance in **D.** v, the vegetal pole

and constitute the first and second germinal layers. The third germinal layer is the **mesoderm,** so called, because it comes between the other two. It arises from the region round the blastopore, where the ectoderm cells gradually pass into the endoderm cells (See Fig. 51, C & D), and grows forwards between the ectoderm and endoderm A layer of cells is now split off from the roof of the archenteron. It divides into a median narrow strip and two broader lateral wings. The former becomes the notochord (See Sect 151), while the latter reinforces the mesoderm.

(60) Sketch a transverse section of an advanced gastrula.

149. Fate of the Germinal Layers.—The entire body of the tadpole and ultimately of the adult are derived from these three primary layers, differentiated so early in development. Each layer keeps up its independent status and makes its own distinctive contribution to the anatomy of the adult

The **ectoderm** or outer layer comes to be associated naturally with the functions of protection and sensation, being the layer that is in immediate contact with the outside world It gives rise to the epidermis of the skin (Sect 64), the epithelium of the stomodaeum and proctodaeum (Sect 153), the nervous system (Sect 150), including the brain, spinal cord, ganglion cells and axis cylinder processes, the important parts of the sense organs, viz., the lens, cornea and retina of the eye, the membranous labyrinth of the ear, and the olfactory epithelium of the nostrils

It is noteworthy in this connection that the nervous system migrates from the surface to the interior in the course of development in adaptation, possibly, to the need for greater protection of its delicate tissue than can be obtained on the surface

The **endoderm** or inner layer derived from the vegetal pole carrying the food-yolk of the embryo is destined to play a similar function in the adult also From it is derived the epithelium of the entire mid-gut and of the digestive glands The latter arise as outpushings of the endoderm, so that their lining epithelia comprising the secreting cells and the epithelia of their ducts are endodermal in origin. The lining of the urinary bladder is similarly derived from the endoderm.

As the ectoderm becomes more and more adapted for a protective function, it loses its respiratory function, which now comes to be performed by the gill-pouches and gills which arise from the endoderm. Paired lateral pouches of the pharyngeal endoderm make their way through the mesoderm and meeting the ectoderm, open on the surface, as gill-slits The gills arise as outgrowths from the lining of the gill-pouches The food-laden water entering the mouth leaves the body by way of these gill-slits, and from it the endodermal epithelium of the gill-pouches and gills absorb the oxygen in exchange of carbon-dioxide Later when the tadpole begins its metamorphosis, the lungs develop, first as a ventral median pouch from the pharyngeal endoderm, but later forking into the paired lungs Thus the lining of the lungs and laryngo-tracheal chamber comes to be endodermal in origin

In addition to these, the important endocrine glands, the thyroid and thymus arise from the endoderm of the anterior end of the mid-gut

The **mesoderm** or middle layer though last to be differentiated accounts for not only the greatest number of organs and tissues of the body, but also for almost the entire bulk of it All the organs lying between the epidermis and the endodermal epithelium (See Fig 3) with the exception of the few already mentioned as arising from the ectoderm or endoderm, are derived from it These include all voluntary and involuntary muscles, the entire skeleton, both bone and cartilage, all kinds of connective tissues, the dermis of the skin, the vascular, excretory and genital systems, the coelomic epithelium, the medullary sheath and neurilemma of the nerve fibres, the neuroglia of the brain and spinal cord, etc

It will be noted that such structures as the skin, gut, lungs, bladder, etc , derive only their epithelia from the ectoderm or endoderm, the remaining portions of their walls being mesodermal in origin

150. The Nerve Cord.—(Fig 52) The nerve cord arises as a groove along the mid-dorsal line of the embryo This is the **neural groove.** On either side of it is a thickened belt of ectoderm called the **neural plate (medullary fold).** The two plates meet in front of the groove, and behind they are produced backwards on either side of the blastopore which has by now become very small (Fig 50, D) The edges of the plates, growing towards the median line, meet each are developed on the surface of the body The embryo now hatches, which means breaking out through the egg membrane and the jelly and passing into a free swimming **larva,** the well known tadpole.

(61) Sketch t s of advanced embyro.

(62) Sketch l s of advanced embryo

154. The Tadpole.—The newly hatched tadpole (Fig 54, 1) is a clumsy little creature with a large head and fusiform body ending in a short compressed tail The mouth has not yet opened There is a **sucker** on the ventral side of the head by means of which the larva attaches itself to some weed or other object On each side, the head bears three short **external gills,** the first set of respiratory organs of the larva

The external gills now grow long, conspicuous and much branched The tail grows longer and flatter and is now used for active swimming (Fig 54, 2) The lashing of the tail is brought about by the V shaped bands of muscles seen on either side The flattened expansions of skin above and below the tail constitute the dorsal and ventral fins. Below the base of the tail the anus is now clearly seen, and the mouth will soon break through and communicate with the pharynx The trunk is still bulging ventrally, as a considerable portion of the food-yolk is still contained in the endodermal cells of the floor of the archenteron

At a later stage (Fig. 54, 3) the **mouth** has opened and is provided with **horny jaws** and teeth, by means of which the larva now begins to brouse upon algæ and other vegetable matter. For such diet as this, the larval gut soon gets adapted by growing enormously in length, i e, nearly eighteen times as long as the head and trunk together. To accommodate this length, the intestine is wound up into a spiral, with two coils running side by side (See Fig 54, 6). Four pairs of **gill-slits** open on the surface in front of the external gills, and the water taken in by the mouth passes out through them In the path of this water, the **internal gills,** the second set of respiratory organs, develop from the epithelium of the gill-pouches, as small folds A fold of skin called **operculum** arises on either side of the head, covering the gill slits and gradually extending backwards cover the external gills The edge of the operculum on the right side fuses with the skin completely, but on the left side complete fusion does not take place, and a small opening called the **spiracle** for the respiratory stream of water is left behind. The external gills now shrivel up The ventral sucker has by this time all but completely disappeared. The larva is now like a fish in appearance, and in the manner of locomotion and respiration, and to a certain extent in feeding.

155. Metamorphosis.—When the internal gills have been functioning for a time, a pair of **lungs** (third set of respiratory organs) make their appearance from a mid-ventral out-pushing of the pharynx. The tadpole is now amphibious and comes to the surface of the water periodically to breathe air Later the gills entirely disappear and the spiracle closes and respiration becomes purely aerial. ✓

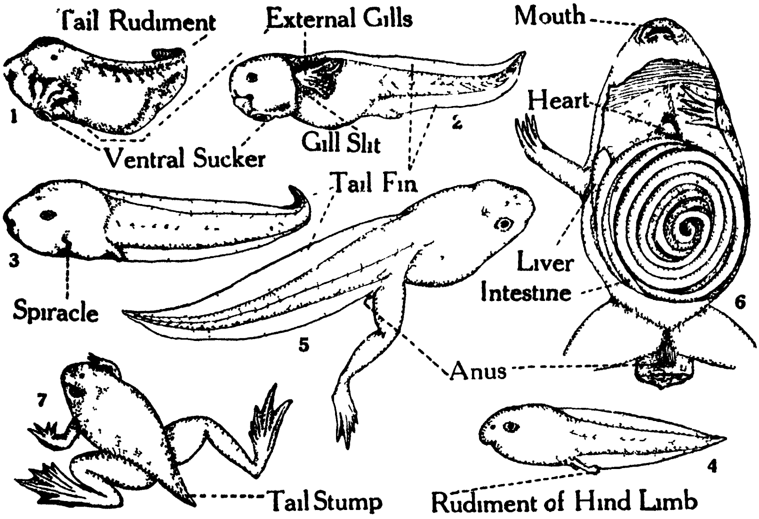

Fig 54 . **1**—**5** and **7** six successive stages in the metamorphosis of the frog, *Rana tigrina* **6**, same as 5, dissected from underside Note the spiral intestine, the small ventral mouth and the left fore-limb still hidden under skin, the right fore-limb has been exposed by dissection (1, × about 4, 2, × about 2, 3, × about 1, 4, × about $\frac{2}{3}$, 5, × $\frac{2}{3}$, 6, × about $1\frac{1}{4}$; 7, × $\frac{4}{3}$)

Meanwhile, the limbs have been developing. The hind-limbs make their appearance (Fig 54, 4) as buds on either side of the root of the tail. They gradually elongate and the various parts are differentiated (Fig. 54, 5). The fore-limbs develop at the same time as the hind-limbs, but remain under the opercula (Fig. 54, 6) and come out only after they are fairly fully grown The left one emerges through the spiracle, while the right bursts the operculum and finds a way out As the limbs grow in size, the tail becomes resorbed gradually (Fig. 54, 7), the material of the tail serving for the nutriment of the larva

The final steps in the metamorphosis consist of the widening of the mouth, the replacement of the horny jaws by true ones, the enlargement of the eyes, the reduction of length of the intestine (to about four times the length of the head and trunk) preparatory to the adoption of a carnivorous diet and the complete absorption of the rudimentary tail A number of important changes also takes place internally, particularly in the blood system, whereby it becomes adapted to meet the needs of pulmonary respiration The young frog now leaves the water and hops on land.

(63) Sketch the various stages in the metamorphosis, illustrating the changes undergone by the external gills, the sucker, tail, limbs, etc

156. What is Metamorphosis?—The term metamorphosis is applied to the changes that a larva undergoes after its hatching, which alter its general structure and mode of life in a marked degree Metamorphosis, then, takes place only in those animals in which the just hatched larva differs considerably from the adult A larva is in all cases a free-living organism capable of independent existence and nutrition In the case of the frog, the larva, called the tadpole, is essentially like a fish, and by the time it has been transformed into a young adult it has lost its typically fish-like characters and taken on those of terrestrial animals The changes it undergoes are concerned, as outlined in the previous section, with adapting the animal for a terrestrial life, as regards breathing, locomotion and nutrition They, however, take place gradually towards the end of the aquatic life of the larva, without any abrupt transition from one stage to the next

It may well be asked, why the terrestrial or semi terrestrial frog returns to water to spawn and why its embryonic and early post-embryonic (tadpole) life take place in water. Why, in other words, is an aquatic prelude necessary for a terrestrial drama? We have at this stage to be content with the authority of biologists who believe that every animal in its individual development repeats briefly the history of the development of the race. If so, the frog must be supposed to have had an early history beginning with a unicellular existence represented by its zygote stage, followed by others, leading to a fish-like existence represented by the tadpole It is hoped, that later on more light may be thrown upon this interesting problem. So we shall proceed forthwith to examine a few more animal types in the chapters that follow.

REVISION QUESTIONS

132 Which part of the egg gives rise to the ectoderm and which to the endoderm of the embryo ?

133 Which is the first essential organ formed in the course of development of the embryo ? What is the significance of this organ taking precedence over all the others ?

134 Does the embryo feed, digest, absorb during its development ?

135 The nervous system arises from the outer germinal layer or ectoderm and migrates into the interior of the body in the course of development What is the significance of this ? How does the central canal of the spinal cord originate?

136 What are the piscine characters of a tadpole ?

137 What are the important landmarks in the progress of the oosperm towards the adult stage ?

138 What is the difference between an embryo and a larva ?

139 Construct diagrams illustrating the segmentation of the zygote up to the 32-cell stage

PART II—PROTOZOA AND INVERTEBRATA

CHAPTER 19

PHYLUM PROTOZOA—AMOEBA, THE PROTEUS ANIMALCULE

Material for Study A culture of Amoebae grown in an infusion of leaves or straw made just alkaline to litmus by addition of a few drops of sodium hydrate and innoculated with a trace of soil (Examine for Amoebae after a day or two), Micro-slides of stained Amoebæ and Amoeba undergoing binary fission

157. A Living Amoeba under the Microscope.—*Amoeba* is a microscopic organism found in the slimy bottoms of pools and ditches, adhering to weeds and other decaying objects A small drop of water from a ditch may contain Amœbae, but in the laboratory they are grown in cultures from which specimens can be readily had for examination.

Mount a small drop from the surface of the culture on a clean slide, cover with a cover-glass and examine under the low power of the microscope When a large specimen has been made out turn on the high power Unless carefully manipulated, the *Amœba* sooner or later moves out from the field of the microscope, showing thereby that it is a living, moving object

Observe closely the locomotion of the organism Note the blunt processes from the body called **pseudopodia** forming and disappearing Some of them are large, and on close examination the material inside the *Amœba* (viz , its protoplasm) can be seen streaming into the largest pseudopodium, which therefore grows continually at the expense of the rest of the body Note also that the animalcule has been moving in the direction of the largest pseudopodium After a time the organism may throw out another pseudopodium in another direction in which it would then move.

Practical work

Note that all along the edge of the animalcule the protoplasm is clear and transparent, whereas, it is granular within The former, peripheral protoplasm is called **ectoplasm** and the latter, the **endoplasm** (cf. Sect 132). In the formation of a psuedopodium, first the ectoplasm bulges out a little (when it can be seen to advantage) and then the endoplasm streams into the little bulging, showing clearly that the latter has a more fluid consistency than the former.

Observe the animalcule for a few minutes continuously, and note the alternate formation and disappearance of a clear round space of a light bluish hue, known as the **contractile vacuole.** It first makes its appearance as a small speck and gradually grows by the accumulation of fluid When it reaches the maximum size it gradually approaches the periphery, and bursting, discharges its contents to the outside After a short interval a new vacuole is formed The gradual expansion of the vacuole is referred to as the *diastole* and the sudden contraction the *systole* The fluid contains the excretory matter drained off with the water from the body of the animalcule If so, the contractile vacuole serves an excretory function.

In addition to the contractile vacuole may be seen a large number of **food vacuoles** scattered all over the endoplasm, containing little droplets of water, in which are immersed the food particles ingested by the animalcule If you observe patiently, you may be able to see an Amoeba ingesting its food The *Amœba* wanders hither and thither, apparently in search of food which consists of diatoms, desmids, smaller Protozoa, bacteria, etc When, in the course of its wanderings, the animalcule comes into contact with any suitable food particle, the part immediately touching the particle ceases to move, while the parts around continue their onward flow, so that the food particle gets caught in a small pit of the ectoplasm with a tiny droplet of water The edges of the pit now grow over the particle, which thus becomes completely immersed in the body of the organism and ultimately passes into the endoplasm, in the form of the food vacuoles already seen *Amœba* sometimes feeds on algae several times its length A filament of *Oscillaria*, for example, is gradually drawn in and coiled up in so doing, until the whole filament is taken in

(64) Sketch three outlines of a live Amœba at intervals of, say, a minute In one of the outlines mark the structures named above in bold type

Practical work

158. A Stained Amoeba under the Microscope.—(Fig 55, A) Examine a stained *Amœba* under the microscope Many of the structural features already noted may be seen in this also, but we can see prominently what was not at all seen in the living specimen, viz , the **nucleus** which is deeply stained (See

Sect 133), lying in the endoplasm. It has the shape of a sphere slightly pressed flat A **nuclear membrane** and several **chromatin granules** can be seen under the high power

(65) *Sketch the stained Amœba under the high power and label the parts*

159. Digestion of Food.—Some of the food vacuoles are seen to be fully loaded, while others contain particles comparatively small for the size of the vacuoles This suggests that the food particles are becoming smaller and smaller, being digested inside the vacuole by a digestive juice secreted by the protoplasm The dissolved food is absorbed into the protoplasm and assimilated Experiments tend to show that Amoebae can digest only protein, and that starches and fats are not digested The indigestible parts are thrown out at the hind end of the body In other words, the contents of a used up vacuole are left behind as the organism trails along.

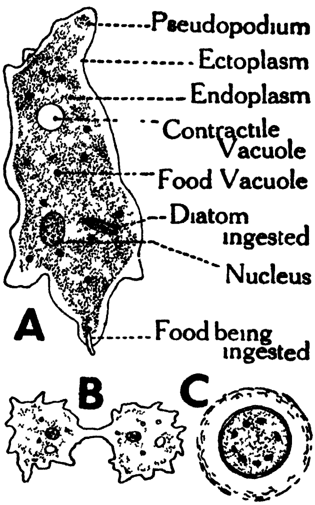

Fig 55 **A,** a stained *Amoeba proteus* under the microscope **B,** an Amoeba about to complete binary fission , **C,** an encysted Amoeba with its nucleus divided into about eight

Digestion in *Amoeba* is *intracellular,* that is within the cell-body, whereas in the frog it takes place in a space bounded by cells (intercellular)

160. Respiration.- If Amoebae are placed in water from which all trace of oxygen has been removed, they cease to exhibit all signs of activity, and very soon die This shows clearly that Amoebae, like all living organisms, have to respire in order to keep up the katabolic activity of the body Evidently Amoebae use the oxygen dissolved in the water in which they live, for respiration, giving out the carbon dioxide into the water

Here we see respiration in its simplest and most fundamental aspect (See Sect 25) There are no elaborate organs as in the frog, and indeed organs of any kind are entirely wanting The contents of the contractile vacuole is said to include CO_2 If so, the contractile vacuole is also respiratory in function.

161. Reproduction.—A young *Amœba* is called an **amœbula.** It is very small with only a single pseudopodium It feeds actively and grows in the course of a few days until it reaches its maximum size Now, apparently the volume of the body compared to its surface has become too large for the proper discharge of the metabolic activities of the cell, since the volume of a sphere varies directly as the cube of its diameter, while its surface varies only as the square The balance between volume and surface area is upset and the latter becomes insufficient for the respiratory and other needs of the cell body This perhaps explains the need for division of the body of *Amœba* into two, which follows the attainment of full size In other words, binary fission takes place and the surface-volume ratio is restored

In **binary fission** (Fig 55, B), the nucleus divides into two, and this is soon followed by the division of the cytoplasm Complex changes like those of mitosis have often been observed in the binary division of Amœbæ The two daughter Amœbæ feed and grow, and in their turn undergo fission When binary fission has taken place a number of times a different method called **sporulation** is resorted to. The *Amœba* rounds itself up into a sphere and secretes by the vital activity of its protoplasm a three layered **cyst** of chitin (Fig 55, C) Enclosed in this cyst the organism can withstand adverse conditions like excessive heat or drought much better than in the naked condition Inside the cyst the animalcule remains quiescent until the return of favourable weather The nucleus now divides into several small nuclei, and the cytoplasm is shared between them. A large number of spores are thus formed and they break through the cyst and become independent amœbulæ

In the encysted condition, *Amœba* may get carried about by wind, water or other means Thus dissemination or dispersal of the species takes place It is the presence of Amœbæ-cysts in the soil that enable us to rear Amœbæ in cultures.

Sometimes *Amœba* resorts to **sexual reproduction.** Two Amœbæ come into contact and their bodies fuse with each other, cytoplasm with cytoplasm and nucleus with nucleus, like two germ cells, and form a zygote. The zygote now encysts and undergoes sporulation or multiple fission.

(66) Sketch the various steps in the binary fission of Amœba.

162. Amœba, a Unicellular Animal.—The entire body of *Amœba* consists of a single cell In other words, Amœba is unicellular. And yet, we note that it is capable of performing all the vital functions which we have learnt to associate with an animal like the frog. Like the latter, the unicellular Amœba also feeds, digests, absorbs and assimilates its food, respires, excretes its waste materials, moves about from place to place, discriminates between what is good and bad for itself, reacts in a particular manner towards impulses produced by heat, light, electricity, pressure, touch, chemical agents, etc , and reproduces its species In the higher animals, exemplified by the frog, each of these functions is performed by a special organ or system of organs made of a very large number of cells How, then, does *Amœba* or any other unicellular organism perform all these functions, though it is not provided with the respective organs?

In the first place, unicellular organisms cannot have any organs since every organ is a multicellular body in itself No organs can be present within the confines of a single cell

It is then not the organs of an animal but the material or substance of which it is made, viz , protoplasm, which is more fundamental The protoplasm of *Amœba* is capable of performing all the vital activities of living organisms, each one of which requires a special organ for its performance in the higher animals In other words, the protoplasm of the various organs of higher animals is specialised for the performance of their respective functions, whereas in *Amœba* no such specialisation has taken place

We can compare *Amœba* to a one-room hut which serves for all the needs of a family like cooking, eating, sleeping, reading, etc , etc , while the frog or other higher animal can be compared to a large mansion with several rooms each designed for a particular purpose The mere fact that the small hut is small makes its upkeep a simple matter, but the large house requires a regular army of servants to keep it clean and in order So also in the higher animals the mere circumstance that the size is large makes the various functions elaborate To take but one example, viz , respiration In a single cell that is in contact with the respiratory medium on all sides diffusion and exchange of gases is simple enough, but in a multicellular animal, only comparatively few cells are in contact with the respiratory medium and the needs of the internal cells cannot be met unless there is some means of carrying the respiratory medium to the interior The lungs, a mechanism for breathing, blood and its special property of absorbing oxygen, and all the other elaborate arrangements associated with internal respiration become inevitably necessary When a part of the body is thus set apart and specialised for respiration, it follows that that part cannot serve efficiently for other functions, and it becomes necessary to have a special organ for each function

The function of reproduction of the species is also performed by *Amœba* and other single celled animals Each organism just divides into two or several smaller ones In the multicellular animals, however, this function is confined, like other functions, to a special set of organs which produce the germ cells There is a distinction in them between the germ producing cells and the other cells of the body, in as much as the germ cells alone can reproduce the species while the tissue cells die out after a time In each successive generation the body dies away, whereas the germ cells carry on, producing both tissue cells and germ cells In the Protozoa, the body-cell is also the germ cell and when it divides (reproduces) and forms new organisms it does not differentiate into several kinds of cells as happens in the Metazoa or multicellular animals

The fertilised ovum or zygote of the Metazoa is capable of giving rise to all the organs of the adult Indeed all the vital functions of living beings are potential in it, just as an *Amœba* or other unicellular organism is actually capable of performing them Hence we see that the protozoan cell body stands comparison with the germ cells of the Metazoa rather than with the cells of adult Metazoa.

REVISION QUESTIONS

140 Which of the two layers of the body of *Amœba* —ectoplasm and endoplasm—do you consider more fluid than the other ? Why ?

141. What are the activities of *Amœba* you have discerned under the microscope, which show the faculty of contraction of its protoplasm ?

142 A marble can be pressed into the interior of a mass of soft clay A food particle is ingested into the body of an *Amœba* What is the essential difference between the two processes ?

143 Why is it that the nucleus is not seen in the living *Amoeba*? What would you do to make it clearly visible under the microscope?

144 What is the meaning of the term 'intracellular'? What is the difference between intracellular and intercellular digestion? Where does each occur?

145 In *Amoeba* change of shape and change of position (locomotion) are identical Explain this statement

146 Wheh seen from above, *Amoeba* appears to be a flat irregular body with pseudopodia in the horizontal plane What is the probable appearance of the organism if you could view it from the side?

147 How do the two Amoebae that copulate and give rise to a zygote differ from the germ cells of one of the higher animals?

148 What are the vital functions of an animal? Is *Amoeba* able to perform all these functions?

149 What are organs? Why is it that an *Amoeba* cannot have organs? Are organs absolutely necessary for the performance of vital functions?

150 What is the difference between a cell like the body of *Amoeba* and a cell from one of the tissues of the frog?

151 What have you learned about the structure of protoplasm from your microscopic examination of Amoebae?

152 What is the approximate size of an *Amoeba*, seeing that the magnification of your microscope is 80, 150, 500?

CHAPTER 20

PHYLUM PROTOZOA (Contd)—PARAMŒCIUM, THE SLIPPER ANIMALCULE

Material for Study A laboratory culture of Paramœcia reared in an infusion of straw or leaves left over till large numbers of Paramœcia appear in it, micro-slides of Paramœcia, stained to show nuclei, micro-slide of Paramœcia in conjugation

163. Live Paramœcia under the Microscope.—(Fig 56) Place a very small drop of the water from the culture on a clean slide, cover with a cover glass and examine under the microscope Unlike *Amœba*, *Paramœcium* darts swiftly across the field of the microscope. This makes observation of active specimens very difficult In order to make the Paramœcia move slowly so as to make observation possible, mix up a few drops of the culture with a little gelatin in a watch glass Place a drop from the watch-glass on a clean slide, cover and examine under the microscope Follow up the movements of a specimen by moving the slide suitably on the stage Note the shape of the body, which has given the name of 'slipper animalcule' to Paramœcium. The broader end corresponding to the toe is, however, the hinder end. The shape, unlike that of Amœba, is definite, though the body can bend and squeeze easily. This is due to the presence of a tough elastic outer layer or **pellicle.** The surface of the body is bristling with a large number of **cilia,**

Practical work

which can be seen to advantage in a specimen which is practically stationary, under the high power. Note the sharp bending of the cilia backwards and the much slower regaining of the vertical position. Immediately under the pellicle is seen a layer containing numerous minute spindle-shaped bodies, called **trichocysts,** placed perpendicular to the surface of the body.

The trichocysts have a remarkable function When a Paramœcium is pursued or irritated in some way, a number of trichocysts are suddenly shot out or exploded, and in so doing they lose their spindle-like shape and become needle-shaped The exploded trichocysts form a mesh work all around the body and effectively keep off the pursuer

Watch a slowly moving Paramœcium Make out the oral groove or **peristome,** beginning near the anterior end of the body on the side which is 'ventral' in the gliding movements of the animalcule, and passing backwards obliquely Its hinder end is deeper than the front and passes into a short tubular gullet called **cytopharynx.** When the animalcule is seen with the peristome uppermost, its anterior end is to the right and its posterior end more to the left The cytopharynx penetrates some way into the interior. Food particles are carried along the peristomial groove and into the cytopharynx by the wave-like movements of the **undulating membrane,** a narrow curtain formed of a row of cilia fused into a sheet

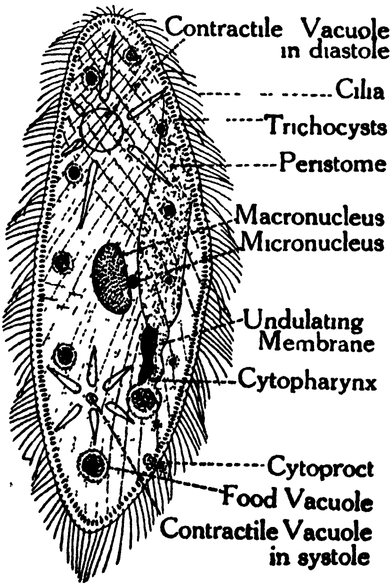

Fig 56 *Paramoecium caudatum* as seen in life, with the nuclei as seen in a stained animalcule. The manner of beating of the cilia is also shown (× 250). (Altered from Minchin).

As in Amœba, there is visible under the microscope an **ectoplasm** and a more fluid **endoplasm.** The latter is more granular, and in life shows a circulating movement within the ectoplasm. If a living specimen is observed long enough, we can see the **food**

vacuole, a droplet of water with minute particles of food, mostly bacteria, forming at the bottom of the cytopharynx, and on reaching a certain size, nipped off into the endoplasm. Similar vacuoles are seen in a long procession circulating in the endoplasm During this circulation, referred to as *cyclosis*, the food is killed, digested and absorbed and the indigestible portions are cast off at a definite spot on the surface, somewhere between the gullet and the hinder end, where the ectoplasm temporarily gives way for the escape of the vacuole This spot is called the cell-anus or **cytoproct.**

Two **contractile vacuoles** are present, one at either end of the body. To watch them forming and disappearing in a live Paramœcium is indeed fascinating The two vacuoles function alternately Each vacuole when full suddenly contracts and voids its contents to the outside (systole) About six to ten radiating channels have already appeared round the position of the vacuole, looking like the spokes of a wheel Each is elongated and spindle like Soon the central vacuole reappears as a small spot and as it grows in size, the radiating channels dwindle so that when the vacuole is fullest, the channels are most shrunken Obviously the vacuole is fed from the radiating channels, which collect waste matter and excess of water from the different parts of the cell When the anterior vacuole is in diastole, the posterior is in systole and *vice versa*

(67) Sketch a Paramœcium under the microscope and mark in it all the parts noted above

164. The Nuclei.—Examine a micro slide of Paramœcium stained to show the nuclei, first under the low, and then under the high power of the microscope Note the large kidney-shaped **macronucleus,** and the smaller **micronucleus** placed on one side of and closely attached to it Both lie in the endoplasm

(68) Sketch

165. The Ectoplasm.—The ectoplasm is of great complexity It consists of four distinct layers, of which the outermost is the pellicle. Inside it is a thin layer showing a fine striation, perpendicular to the surface. Next inside comes the layer containing the trichocysts The innermost layer is spongy with droplets of water in its meshes The surface of the ectoplasm shows a hexagonal pattern This is due to the pellicle being pitted all over, and at the bottom of each pit is a little hole through which a cilium passes out. The cilia, therefore, are not attached directly on the surface, but spring from the layer beneath the pellicle. This accounts for its striated appearance.

166. Locomotion.—Doubtless, you have seen under the microscope two kinds of locomotion, *creeping* and *swimming* Amongst debris or other obstacles in its path, *Paramœcium* glides along using the cilia of its oral surface as if they were little legs The body can be bent or squeezed for passing through a narrow crevice or rounding a sharp corner

The rapid concerted and repeated movements of the cilia are responsible for the swimming movements The backwards and sideways beat of the cilia propels the body onwards The direction can be reversed by the cilia beating forwards The larger cilia of the oral region cause a vortex of water carrying food particles to be pulled into the mouth Here also, then, as in *Amœba*, locomotion and food-catching are closely related

The path traced by a moving *Paramœcium*, however, is not straight, but spiral The organism moves forwards and at the same time rotates on its own axis In addition to this the anterior end of the body swerves from the axis of movement, so that the oral groove is always facing the axis The spiral course is the resultant of three kinds of movements

First, the backward stroke of the cilia

Second, the sideways (to the left of the observer) stroke of the cilia First and second together result in the organism moving forward spinning on its own axis

Third, the beat of the large cilia of the peristome This causes the anterior end to be shifted away from the axis of movement

Sometimes you see a *Paramœcium* entangled among the debris, caught by its posterior cilia and unable to move forwards The second and third factors alone determine the movement of the animalcule in such a predicament, and the body describes a cone with the posterior end as the apex and the mouth always facing the axis of the cone If now the organism gets released, the cone gets projected forwards along its axis, and at the same time spinning on it, any point on the edge of the cone describing a spiral

The spiral course enables the organism to cover more territory, test more samples of water and select more quickly favourable feeding grounds, avoiding the less favourable ones, than it would be possible by moving merely in a straight line.

167. Reproduction.—As in *Amœba* binary fission takes place under normal circumstances In fission the two nuclei elongate, become dumb-bell shaped and finally snap in the middle,the half nuclei now being lodged near the ends of the cell-body, which soon follows suit, by constricting around the middle of its length, in a transverse plane and ultimately breaking into two The two daughter-individuals have the contractile vacuoles, mouth-opening and cilia shared among themselves, as well as the nuclei , while the peristome goes entirely to the anterior end-daughter, the other developing one for herself before fission Each of the daughter Paramœcia becomes free-living, and feeding actively grows to the normal size and undergoes binary fission in its turn, in the course of 24 hours This rate of multiplication is indeed a very high one and if circumstances are favourable over 1200 million offspring will be produced in 50 days starting with a single individual In a certain species of *Paramœcium,* it has been shown that by daily renewing the culture medium, Paramoecia can be made to go on indefinitely multiplying by binary fission But under natural conditions, in which the environment is never constant, it is noted that after a number of successive divisions, a general enfeeblement of the vital processes occurs accompanied by dwarfing of the individuals This condition of senility would soon end by the extermination of the race, but for the fact that a process known as conjugation supervenes resulting in an exchange of micronuclear matter between two senile individuals and a rebuilding of the macronucleus from the micronuclear substance.

168. Conjugation.—(Fig 57) The senile Paramœcia correspond to the gametocytes of the frog, because, like them they undergo a process of maturation resulting in the formation of gametes. In conjugation, the **gametocytes** come together in pairs, the members of a pair meeting each other by their ventral surfaces. They stick together by their ectoplasm and move about in the paired condition The micronucleus of each member of the pair divides twice repeatedly by mitosis. Of the four micronuclei thus formed three disintigrate and disappear, leaving only one behind. This divides again into two, one of which is larger than the other and called the macrogamete or **female pronucleus,** while the other is much smaller and called the microgamete or **male pronucleus.** The male pronucleus of each member of the pair now migrates towards the female pronucleus of the other and fertilises it In other words, syngamy takes place The two Paramoecia now separate, each exconjugant being a zygote since it contains a **zygote nucleus,**and lead independant lives actively swimming about and feeding

Each of them, like the zygote of the frog, is now capable of active cell-division The macronucleus in each degenerates and is absorbed by the protoplasm On the other hand, the zygote nucleus divides thrice repeatedly and results in eight nuclei, in two groups of four, one at each end of the Paramoecium Binary fission now takes place, each of the daughters having four nuclei Two of these enlarge and become macronuclei, while the others retain the nature of micronuclei. Another division soon follows and the grand daughters, each with a macro and a micronucleus, now feed and attain the adult proportions The macronucleus is once again active, i e, the race of Paramoecia is rejuvenated.

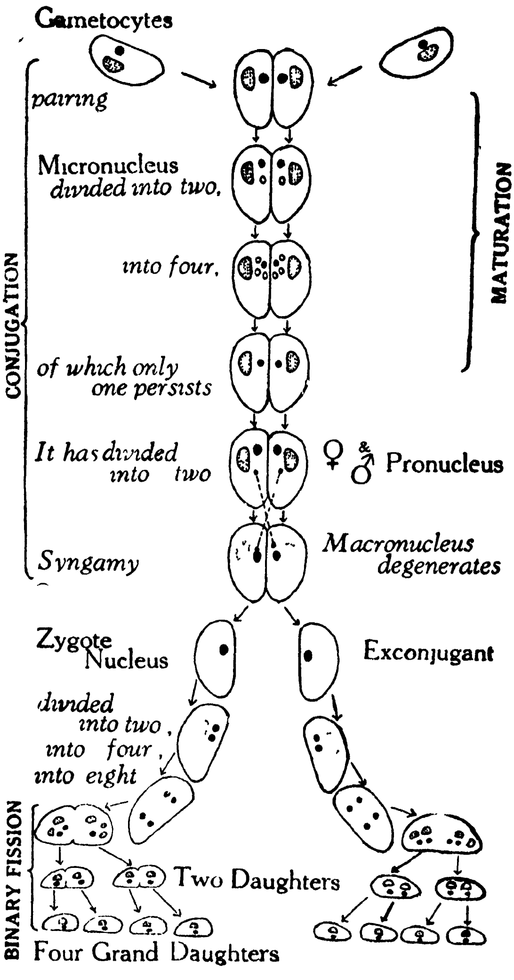

Fig 57 A diagram of conjugation followed by binary fission in *Paramœcium caudatum* Macronucleus, dotted, micronucleus, dark

Conjugation brings about two results Firstly there is the fusion between nuclei derived from two individuals, a sexual process allied to fertilisation in the higher animals, and secondly, the rebuilding of a macronucleus from the micronuclear material The latter effect can also be produced, without the former, that is, a new macronucleus can be built up from micronuclear material without two individuals conjugating The name **endomixis** has been given to this Whether sexual fusion between two nuclei takes place or not, it seems to be essential that periodically the macronucleus must be replaced by a new one derived from the micronucleus

(69) *Sketch slides showing conjugation*

REVISION QUESTIONS

153 Place a small drop of water containing Paramœcia on your thumb-nail Can you see the organisms? How do they compare in size with Amœbae?

154 How does the shape of Paramœcium differ from that of Amœba?

155 How far can you use correctly the terms anterior, posterior, dorsal, ventral, right and left in connection with Paramœcium?

156 Paramœcium has a definite mouth, anal spot, front and hind ends, definite positions for the contractile vacuoles, etc How do you relate these with the constant shape of its body?

157 The ectoplasm of Paramœcium is more rigid than the endoplasm, and the pellicle is a specially toughened layer of it The endoplasm moves relatively to the ectoplasm How far can we say that the ectoplasm serves as an exoskeleton of the animal?

158 The macronucleus in Protozoa is said to control the vegetative and the micronucleus the reproductive activities of the organism Can you find any evidence in support of this view from the study of Paramœcium?

159 Amœba is potentially immortal, that is, barring accidents it can go on living into the future generations infinitely Can the same be said of Paramœcium, of a Vertebrate?

160 The micronucleus gives rise to both micro- and macro-nuclei, while the macronucleus dies away before the exchange of gametes takes place Is there any similar phenomenon observed among the higher animals? If so, what?

161 The oosperm (zygote) of the frog divides, but the daughter cells keep together The exconjugants of Paramœcium also divide, but the daughter cells do not keep together What difference does this behaviour of the daughter cells bring about between the adults of the two organisms?

162 Remembering that Paramœcium is much larger than Amœba, suggest a reason for the presence of two contractile vacuoles with radiating channels

163 It is seen experimentally that senile Paramœcia descended from the same parent do not conjugate with one another, but only with those belonging to a different strain What is the significance of this?

CHAPTER 21

PHYLUM PROTOZOA (Contd)—EUGLENA

Material for Study Collect water from stagnant pools and puddles after the rains, especially water with a greenish tinge Live Euglenæ are in most cases responsible for the colour, micro-slide of Euglena stained for nucleus

Practical work

169. Live Euglenæ under the Microscope.—Place a very small drop of water containing live Euglenæ on a clean slide, cover with a cover-glass and examine under the microscope Euglenæ may be seen as spindle shaped green bodies (Fig. 58), much smaller than Paramœcia. Their green colour helps to distinguish them easily from other organisms They move more slowly than Paramœcia and are therefore more readily observed under the microscope Note that the forward end is blunt, while the hinder one tapers to a fine point Observe how the body is bent, squeezed and contorted, showing that there is a limiting membrane or **pellicle** as in *Paramœcium* Make out the **ectoplasm** and **endoplasm** and within the latter, several oval or elongated bodies, called **chromatophores.** What is the green colour due to? Scattered about in the endoplasm are also a number of smaller bodies without any green colour. These are **paramylum** bodies, made of a substance having the same formula as starch. At the anterior end, on very careful examination, is seen a slender whip-like process or **flagellum,** lashing about in the water. Where it leaves the body is a deep, narrow **gullet** opening at the anterior end by the **mouth,** and passing internally into a wide **reservoir,** which with the gullet looks like a small flask The flagellum arises by a double root from the bottom of this reservoir, a fact that can be made out only in specially stained slides under very high magnification A red pigment-spot or **stigma** is seen against one side of the reservoir whose colour is due to the presence of minute granules of hæmatochrome. In the vicinity of the reservoir

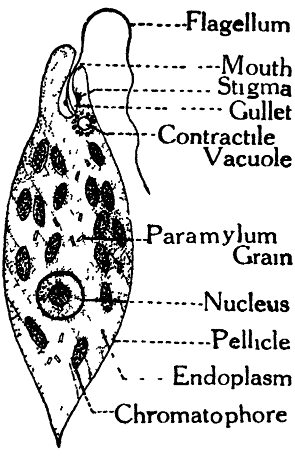

Fig 58 *Euglena viridis* (× 1000)

is a **contractile vacuole** surrounded by a few much smaller feeder-vacuoles, the latter bursting and passing their contents into the former, which in its turn contracts and empties itself into the reservoir. From the reservoir the waste materials can escape into the water No food vacuoles are usually seen in the green Euglena (*Euglena viridis*)

As the water under the cover-glass dries up, the Euglenæ, as it were, feel uneasy and their bodies are thrown into different shapes, some bulging out in the centre, others constricted at one or more places These and similar movements are called *Euglenoid* movements The surface of the cuticle shows a spiral striation

(70) Sketch living Euglenæ showing all the parts printed above in bold type

170. The Nucleus.—Examine the slide of stained Euglenæ A large round nucleus is seen a little behind the middle One of the roots of the flagellum lying in the reservoir carries a deeply stained thickening, *placed opposite the stigma* This is called a **basal granule** or **blepharoplast**, and is believed to be a centrosome in relation to the locomotor organ, viz, the flagellum It may therefore be considered as part of the nuclear apparatus

171. Locomotion—You have noted that the flagellum lashes about in all directions and its free end can be seen bending backwards, not unlike the movements of a swimmer's arms Note also that in moving forward the body spins on its axis, tracing a spiral path, as in *Paramœcium*

Since the flagellum pulls the body after it, it is distinguished as a tractellum from one that pushes it from behind or pulsellum An example of the latter is furnished by the tail of a sperm

172. Euglenæ and Sunlight.—Into a shallow dish with a flat bottom, pour some water distinctly coloured green by Euglenæ Expose the dish to bright sunlight and cover one half with a piece of board Remove the board after ten minutes Note how the Euglenæ have all collected in the region midway between the covered (dark) and well-lit areas This shows that Euglenæ prefer diffused sunlight and shun darkness as well as direct light.

Practical work

The stigma and basal granule afford an explanation for this behaviour of the animalcules towards sunlight If in its aimless wander ings (for you have seen the animalcule always moving from place to place), it comes into a region of moderately bright illumination, the light falling upon the stigma would transmit an impulse to the basal granule which regulates and controls the movement of the flagellum and prevents the animal leaving the favourably lit region If now the light is intensified or reduced, a different impulse may cause the flagellum to move in such a manner that the organism moves away from the spot. The stigma, then, enables the organism to behave in a *positively phototropic* manner

173. Sunlight and Nutrition.—The chromatophores contain the characteristic plant pigment, chlorophyll They have the power, therefore, of breaking down carbon dioxide into oxygen and carbon and of combining the carbon with water to form the carbohydrate, paramylum The organism, then, feeds like the green plant by utilising the sun's energy for the manufacture of organic food In other words, it manufactures food photosynthetically Why Euglenæ are positively phototropic is now easy to understand

174. Other Modes of Nutrition.—Nutrition by photosynthesis is the plant-method of feeding and is called **holophytic.** But *Euglena* can keep itself going even when kept out of sunlight It can absorb through its surface solutions containing decomposing organic compounds including carbohydrates and nitrogenous compounds, even in the dark The chlorophyll is then of no use and is lost This type of nutrition is characteristic of fungi and is called **saprophytic.** Some species of Euglenæ are able to ingest solid food particles through the mouth and digest them inside food vacuoles This is the typical animal method, known as **holozoic.**

175. Pyrenoid.—In addition to the grains of carbohydrate material, viz., paramylum, Euglenæ often contain in their bodies a proteid accumulation in the form of a rounded body called the pyrenoid Paramylum grains are often seen encrusting the pyrenoid, and hence, it has been suggested that it is a centre of starch-formation It may be that it is a store of proteid food.

176. Reproduction.—*Euglena* has not been known to reproduce sexually *E viridis* reproduces by longitudinal **fission** in the motionless condition In doing so, the body first becomes spherical and locomotion stops. A mucilaginous coat is secreted round the body and the flagellum disappears. First the pyrenoid and the nucleus divide after elongating transversely followed by the division of the cytoplasm. Thus two daughter-Euglenae still contained in the mucilaginous envelope are formed Instead of getting freed from the cyst, they go on dividing within the coat, so as to give rise to a large number of small Euglenae **Encystment,** as in *Amœba,* also takes place, presumably under adverse conditions, and results in the formation of thirty two **flagellulae** or baby-flagellates in the same cyst, which now escape and grow to the adult size

Certain species of Euglenae are known to undergo longitudinal fission in the active free-swimming condition

177. Biological Importance.—We have seen that *Euglena* is a sunlight-loving organism provided with chlorophyll and capable of nutrition in a plant-like manner On the other hand it swims about and (at least some species) ingests food, characters usually associated with animals Here, then, we have an organism which exhibits both plant and animal characters The Flagellata, the class of Protozoa to which *Euglena* belongs, furnishes also other examples of organisms, which can at once be classed with plants as well as animals, thus serving to bridge the gulf between the two great kingdoms comprising Living Beings.

REVISION QUESTIONS

164 *Euglena* has been assigned to the Algæ, as well as to Protozoa Give reasons which support the rival claims What do you think of its true position among living beings?

165 Show that in *Euglena* as well as in other Protozoa you have studied, locomotion and feeding are closely related

166 What are the different modes of nutrition met with in *Amœba, Paramœcium, Euglena* and the malarial parasite?

167 Introduce a little drop of water containing Paramœcia into a slide of live Euglenæ, and compare their sizes

168 How would you show that sunlight is essential for the normal, healthy life of Euglenæ cultured in the laboratory?

169 Devise a simple experiment to show that oxygen is given out of a culture containing green Euglenæ

CHAPTER 22

PHYLUM PROTOZOA (Contd)—PLASMODIUM, THE MALARIAL PARASITE—CHARACTERS AND CLASSIFICATION OF PROTOZOA—MODES OF LIFE OF PROTOZOA—PARASITISM

Material for Study Micro-slides of *Plasmodium vivax* in human blood, micro- and macrogametes inside the stomach of *Anopheles*, oocysts in the stomach-wall of *Anopheles*

178. Malaria.—Malaria is one of the commonest of diseases of man, especially in the tropics It is still believed by many people that malaria is brought about by some peculiarity of the water in the hilly and marshy tracts where it is most prevalent In Europe, it was thought to be due to the 'bad air' from which the name *mal-aria* has been given It is, however, now definitely known that the disease is caused by the parasitic Protozoan, *Plasmodium*, which infects and lives at the expense of the red blood corpuscles, reducing them both in vitality and numbers, and ultimately bringing about the death of the host This discovery was made by Dr Laveran, a French military surgeon in 1880, but how the parasites got admission into the blood was not known till 1897, when Major Ronald Ross of the Indian Medical Service discovered the parasites in the stomach of *Anopheles*, one of the common mosquitoes feeding on human blood The life-history of the parasite is thus completed in two different hosts, viz, the vertebrate, man, and the invertebrate, mosquito In the human blood, schizogony or multiple fission takes place, while in the mosquito syngamy and sporogony or spore-formation take place

179. Schizogony.—(Fig 59, A) The parasite can be obtained for microscopic examination by preparing smears of the blood of a malarial patient taken at the end of one of the febrile attacks so characteristic of the malady The parasites are then seen in the form of **amœbulæ** creeping inside the red blood corpuscles An amœbula is a young parasite which has entered upon the feeding stage in the corpuscle and may therefore be called a **trophozoite.** It grows by absorbing nutriment from the red blood corpuscle In the early stages of growth, a drop of fluid accumulates in the body and shifts the nucleus of the parasite to one side, giving it the appearence of a signet ring. As growth proceeds the vacuole disappears, and small granules of **melanin,** a black pigment (a product of digestion by the parasite of the pigment hæmoglobin) is deposited in the corpuscle. When full grown the trophozoite has almost completely filled the blood corpuscle and is ready for schizogony The full-grown trophozoite is therefore called a **schizont.** Repeated nuclear division of the schizont results in the formation of several nuclei, each of which gets surrounded by some protoplasm, so that a large number of **merozites** are formed The corpuscle now bursts and the merozoites escape into the plasma of the blood along with the melanin granules Each merozoite now infests a fresh blood-corpuscle, and the entire schizogony is repeated several generations

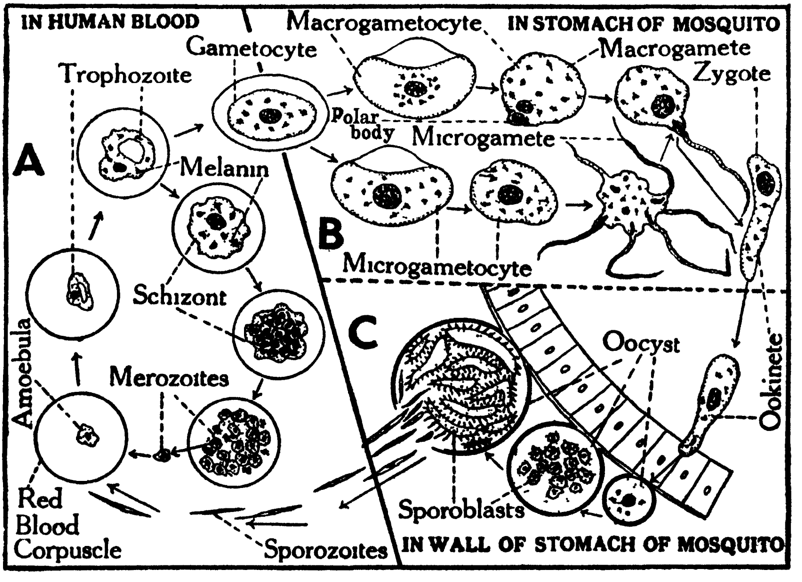

Fig 59 Life-cycle of *Plasmodium*, diagrammatic **A**, schizogony, **B**, syngamy, **C**, sporogony

Now, assuming that only a few parasites are introduced into the blood of a healthy human being (by the bite of a mosquito) a varying period of time will elapse before a sufficiently large number of red blood corpuscles are affected, so as to tell upon his health. This period is called the period of incubation, the end of which is marked by the first attack of fever The next attack comes on after forty-eight hours, which is the time required for a schizogonous cycle (See Sect. 182) in *Plasmodium vivax*.

The onset of fever marks the time, at the end of each schizogonous cycle, when the merozoites are set free into the plasma. Certain toxins resulting from the metabolic activity of the parasites are also freed into the plasma and account for the febrile attack itself

The continued destruction of the red blood-corpuscles of the host would in time bring about the death of the host and with it the extermination of the parasite But in case a mosquito has bitten the patient, some of the parasites sucked in by it would serve to complete the life-cycle by syngamy and sporogony

(71) Sketch the slide of Plasmodium in human blood

180. Syngamy.—(Fig 59,B) The sexual phase culminating in syngamy is initiated by some of the full-grown trophozoites in the human blood becoming **gametocytes** instead of schizonts These are from the beginning, of two kinds, male and female A mosquito happening to feed upon the blood of a malarial patient sucks in both schizonts and gametocytes, but the latter alone survive in the stomach of the new host, the others being killed and digested The female or **macrogametocytes** are larger in size with smaller nuclei and their protoplasm stains more deeply than the male or **microgametocytes.** A process of maturation now takes place in the macrogametocyte, a portion of its nucleus being extruded as a polar body It can now be called a **macrogamete** or female germ cell The nucleus of the microgametocyte divides into about six which pass to the surface, and become elongated and provided with a thin covering of protoplasm and form long, slender, motile bodies, which ultimately get liberated into the stomach of the mosquito Each of these corresponds to a male germ cell, being filamentous and capable of lashing movements It is called a **microgamete.**

(72) Sketch the slide showing micro- and macrogametes inside the stomach of the mosquito

A process of conjugation now takes place. A cone of attraction is formed on the surface of each macrogamete, and a microgamete penetrates its way through this cone into the macrogamete, within which its nucleus rounds off as a male pronucleus The two nuclei fuse and a **zygote** is formed.

181. Sporogony.—(Fig. 59, C) The zygote soon loses its spherical shape and becomes actively moving—hence called **ookinete**—inside the stomach of the mosquito and penetrating the wall of the stomach rounds off and encysts itself underneath the outer epithelium. In this position the entire body grows in size.

(73) Sketch the slide showing zygotes in the stomach-wall of Anopheles

The encysted cell called an **oocyst** now divides into a number of smaller cells called **sporoblasts** from the surface of each of which a very large number of spores or **sporozoites** are formed by further cell division, leaving an amount of residual cytoplasm. Innumerable spores result from a single cyst, each being a minute spindle-shaped body pointed at either end and having a nucleus in the middle The mature sporozoites break through the cyst-wall into the body cavity of the mosquito and ultimately reach and penetrate the salivary glands (See Sect. 308)

When the mosquito bites a human being a number of the sporozoites are transmitted into his blood along with the saliva. Each sporozoite penetrates a blood corpuscle, becomes an amoebula and starts on the schizogonous cycle

(74) Sketch the slide of oocysts in t s stomach of Anopheles.

182. The Malarial Parasites.—Three distinct species of Plasmodium are known and associated with three different types of malarial fever These are *Plasmodium vivax, P malariae* and *P falciparum (Lavarania malariae)* The main differences between these parasites are set out in Table 6.

TABLE 6

MALARIAL PARASITES, COMPARED

	P VIVAX	P MALARIAE	P FALCIPARUM
Type of Fever	Tertian	Quartan	Tropical, Malignant or Pernicious
Period of Incubation	14—18 days	18—21 days	9—12 days
Period of Schizogony	48 hours	72 hours	24—48 hours
No and arrangement of Merozoites	15—24, in 2 rings	6—12, in a rosette	8—10 or more, irregular
No of Parasites in Blood Corpuscle	One	One	Twd or more
Gametocytes	Spherical or ovoid	Spherical or ovoid	Sausage-shaped
Peripheral Blood contains	All stages	All stages	No segmenting stage

183. Characters of Protozoa.—The Protozoa are animalcules like *Amoeba, Paramoecium, Euglena* and the malarial parasite in which the cell is the individual or organism, unlike the frog and other higher animals in which a large number of cells go into the make up of the organism or individual Thus the cellular structure so characteristic of the higher animals (and plants) is absent in the Protozoa (except perhaps the colonial Protozoa) Most Protozoa have a single nucleus, but some have two, like Paramoecium, while others may have a larger number The unicellular Protozoa, like Amœba or Paramœcium therefore, correspond to the germ cells of the cellular organisms Both the germ-cells of the higher animals and the body-cells of the Protozoan organism are capable of repeated binary fission, but in the case of the former, the products of fission keep together within the egg-membrane and give rise to the embryo and ultimately to the adult, while in the latter the products of each successive fission swim away from each other This might have been considered diagnostic of the Protozoa, but for the fact that certain Protozoa tend to form colonies by repeated binary fission like the metazoan embryo, by remaining organically connected together and leading a common life. Tissue differentiation as we have found it in the frog, however, is characteristic of the animals above the grade of the Protozoa, while it is entirely lacking in them, so that the Protozoans and higher animals may be appropriately distinguished as **Cytozoa** or cell-animals **Histozoa** or tissue-animals respectively

184 Classification of Protozoa.—Protozoa are classified into four classes —

i. Class Sarcodina. Protozoa without a pellicle or limiting membrane, which enables the organisms to throw out pseudopodia, hence the amoeboid form is predominant and locomotion pseudopodial Usually a single nucleus Examples — *Amoeba*, *Entamoeba histolytica*, the parasite of amoebic dysentery.

ii. Class Mastigophora or **Flagellata.** Protozoa with a definite pellicle or cell-wall and one or more flagella, hence, locomotion is by the lashing of the flagella Usually a single nucleus. Examples.—*Euglena*, solitary, fresh-water, *Volvox*, colonial, fresh-water, both provided with chlorophyll, *Noctiluca*, marine, phosphorescent, *Trypanosoma*, the parasite of sleeping sickness, *Leishmania*, the parasite of kala-azaar, *Trichomonas*, causes a kind of dysentery in man,

iii. Class Ciliophora. Protozoa with a definite pellicle provided with cilia, hence locomotion is ciliary Usually a macronucleus and a micronucleus. Examples ·—*Paramoecium*, fresh-water, with a uniform covering of cilia, *Vorticella*, fresh-water, with a circlet of cilia round the peristome; *Zoothamnium*, similar to Vorticella, but colonial; *Opalina*, with a large number of nuclei, parasitic in the rectum of the frog; *Balantidium*, parasitic in the human intestine, causes a kind of dysentery

iv. Class Sporozoa. Protozoa with no locomotor mechanism, endoparasitic in Histozoa (Metazoa) Reproduce by spores Examples — *Plasmodium*, the malarial parasite; *Monocystis*, parasitic in the seminal vesicle of the earthworm, *Gregarina*, intestinal parasites of several Arthropodes.

185. Modes of life of Protozoa.—The majority of Protozoa are aquatic in **habitat.** All Protozoa require a certain minimum humidity below which they cannot sustain life This minimum varies widely in the different groups of Protozoa Thus while most are inhabitants of fresh-water or the sea, others are parastic and live inside the vital fluids of other animals or even of plants, and one group, the Mycetozoa, lives a semiterrestrial life No Protozoan can however lead an active life in completely dry surroundings, and the formation of resistent cysts is resorted to when excessive drought threatens

Their **modes of feeding** vary in the different groups and more than one mode sometimes may be seen in the same animal This is particularly the case in some of the free-living Mastigophora Thus in *Euglena* we have seen that the holozoic, holophytic and saprophytic methods coexist **Holozoic** forms are active food catchers which ingest the prey and digest them in food-vacuoles inside the body In other words they require ready-made protein derived from other organisms to build up more protoplasm for themselves Most of the Sarcodina and the Ciliophora are holozoic, while several Mastigophora also live in a true holozoic fashion or combine more than one kind of nutrition as in *Euglena*

Holophytic forms are mostly confined to the Mastigophora. In such flagellates there exists one or more chromatophores or colour-bearing corpuscles containing the characteristic plant-pigment chlorophyll or some other pigment of allied nature. These pigments have the power of decomposing carbon dioxide in the presence of sunlight, and making use of the carbon for the building up of carbohydrates and other constituents of the living body **Saprophytic** forms get their food ready-made in the form of organic substances in solution, the products of metabolism or decay of other living organisms This they are able to absorb through their body-surface and build up into the more complex protoplasm of their own It has, however, to be remembered that there are but very few organisms which subsist entirely in a saprophytic manner

In certain Sarcodina, viz , the Radiolaria, small green or yellow algae inhabit the interstices of the numerous vacuoles found in the ectoplasm The association in such cases is between a holophytic and a holozoic organism The respiratory product, viz , carbondioxide of the latter is made use of by the holophyte, which in return supplies the holozoic partner with substances which it has manufactured photo-synthetically Such a mutually beneficial association between two organisms is called **symbiosis.**

Finally, there are **parasitic** Protozoa which inhabit the bodies of other animals, living at the expense of their hosts, mostly Metozoa.

186. Parasitism.—Parasites are either epizoic or entozoic The **epizoic** parasites live upon the bodies of other animals from which they may derive shelter, support, a free passage and occassionally food Such apparently harmless parasitism may however lead on to a state in which the parasite begins actively to feed upon the skin or other tissue of the host. This is found to be the case in some epizoic parasites of fishes, e g., the flagellate *Costia* **Entozoic** parasites are internal parasites and live in the alimentary canal, tissues or vital fluids of the host An example of gut-dwellers which are harmless to the host is furnished by the Flagellate, *Trichomonas* On the other hand the Ciliate fauna of the stomachs of ruminants intercept the raw food of the hosts, while the Gregarines as a group go a step further and absorb their digested food From such cases of apparently harmless parasitism, we pass on to the more lethal cases in which the parasite begins actively to feed upon the tissues of the host as in *Entamoeba histolytica*

187. Effect of Parasitism upon the Host.—Just as there are varying degrees of parasitism, the effect of parasitism upon the host also varies As a rule a particular parasite is associated with a particular host, and the latter may not at all be affected by harbouring the parasite It may be that the damage done by the parasite is quickly repaired Such is the case in most epizoic forms and in a large number of the entozoic forms living in the intestines of the host. But even strictly internal parasites like Trypanosomes may apparently be harmless to their hosts This is obviously to the advantage of the parasite since the well-being of the host means also the well-being of the parasite It is presumable that in all cases of long association between the parasite and the host, the latter becomes immune to the effects of parasitism Thus the wild cattle of Africa and the tse tse flies do not seem to suffer at all even though they carry hoards of Trypanosomes, but a comparatively newer host like man or the domesticated cattle suffer very much from the attacks of the same parasites Again the Gregarine parasites, which are harmless to invertebrate hosts like the cockroach and other Arthropoda (Chapters 29 & 30) in which they are always found in enormous numbers, seem to affect the mammalian hosts lethally even when their numbers are few In all cases of incomplete adjustment between the parasitic and the host, or where there is no adjustment at all, the effect of parasitism may be the death of the host This may result from the destruction of the tissues of the host, as for example, the red blood-corpuscles or from the discharge of poisonous toxins and excretory waste into their bodies or from both

188. Effect of Parasitism upon the Parasite.—As a result of parasitism the parasite suffers racial degeneration In the typically parasitic group of Protozoa, viz, the Sporozoa, we see that all the organellæ we usually associate with normal active life of the Protozoa such as locomotory, food-capturing and ingesting organellæ, contractile vacuoles, etc, are wanting Neither do we meet with any protective skeletal structures Even members of the Mastigophora like Trypanosomes have lost the organisation of the class in proportion to their parasitic nature, the flagellum alone remaining to bear witness to their Flagellate affinities.

189. Dissemination of the Parasite.—This is brought about in various ways. In the case of those parasites which live in the alimentary or other passages of the host from which there is a natural anatomical outlet, the parasites may pass out of the body into the surrounding medium and reinfect new hosts But this simple method of transference is not possible in the case of parasites living in the blood and other closed spaces of the host In such cases either the death and decay of the host has to liberate the parasites or the parasites have to be transmitted actively from host to host by the agency of an intermediate host, which in most cases is a biting animal, such as an insect, leech, etc In a few cases tumours and ulcers may result and the parasite escape through the pus Direct contact as in the case of *Trypanosoma equiperdum* is also one of the methods of transmission In the case of *Nosema bombysis*, the parasite of pebrine, transmission takes place though the eggs of the silk-worm resulting in the hatching out of an already infected caterpillar (See Sect. 319).

REVISION QUESTIONS

170 Plasmodium is parasitic Its powers of locomotion are very limited and it moves only during certain phases of its life-history Is there any relation between these two?

171 What is the food of Plasmodium? How does it take its food? Is it able to digest and absorb food? Does it excrete any waste products? Has it got any organelles for these functions?

172 How do you distinguish between multiple fission, schizogony and sporogony?

173 Is there any parallelism between the reproductive cycle of Paramœcium and that of Plasmodium?

174 Distinguish between Protozoa and Metazoa.

175 What is the mode of feeding in Amœba, Paramœcium and the malarial parasite?

176 Distinguish between parasitism and symbiosis

177 Explain how parasitism brings about racial degeneration of the parasite

CHAPTER 23

THE PROTOZOA (Contd)—HUMAN PARASITIC PROTOZOA
THE PRINCIPAL PHYLA OF ANIMALS

Material for Study Micro-slides of *Entamœba histolytica*, *Trichomonas hominis*, *Trypanosoma gambiense* in human blood, *Leishmania donovani* in human spleen and *Balantidium coli*

190. Protozoa and Disease.—Protozoa are responsible for various aliments of man and other animals including the domesticated. Some of these like malaria and sleeping sickness, are among the most terrible of human scourges, while others are of little or no consequence as diseases and the presence of the parasite may not lead to any pathological symptoms In the case of *Monocystis*, a sporozoan parasite of the earthworm the presence of the parasite does not produce any deleterious effect on the host and the malarial mosquito does not seem to be worse off for harbouring the gametocytes and oocysts of *Plasmodium* Or again, the wild cattle of Africa harbour the Hæmoflagellate *Trypanosoma brucii* transmitted by the tse-tse fly and neither host is affected by the presence of the parasite On the other hand imported cattle die off in large numbers when the parasite happens to gain admission into their blood It would therefore appear that the parasites are pathogenic only when they happen to pass into the bodies of newer hosts which are not accustomed to them In the new host conditions for the parasite may be ideal, and it may multiply enormously in an asexual manner and increase to such an extent as to destroy the blood-corpuscles or other tissue and excrete toxins, thereby causing the death of the host

191. Immunity.—But such fatal results for the host would often mean the destruction of the parasite also, and it is certainly to the advantage of the latter that the host is not killed off in this manner By long association between the parasite and the host through countless generations, we can imagine, a state of equilibrium will be reached between the two when the host becomes immune to the presence of the parasite and the parasite does not so unduly multiply as to be a menace to the tissues of the host.

Such a state of equilibrium is reached in somewhat the following manner A protozoan infecting a new host and finding conditions of life favourable would multiply enormously and bring about the death of the host In course of time such of the individuals of the host-species which cannot harbour the parasite with immunity will be weeded out by natural selection and only those that can withstand the parasite will be allowed to live and reproduce giving rise to progeny that have inherited the ability to resist the evil effects of the parasite Thus in course of time, the entire species would become more and more immune to the particular parasite

Depending upon the degree of immunity which the host has attained it behaves to the parasite either as **susceptible,** i e, the parasite lives and multiplies in the host to such an extent as to interfere with its health, the degree of immunity being least; **tolerant,** i. e., the parasite lives and multiplies, but not to such an extent as to cause perceptible interference with the health of the host, the degree of immunity in this case being higher, or **repellent,** i. e , the intruding parasite is killed off and destroyed by the host, no question of immunity arising in this case.

When due to the introduction of the parasite or the host into a new locality, a parasite gains access to a new host, there occur violent outbreaks of disease which would last till the more susceptible strains have been weeded out, with the survival of the tolerent or repellent strains, in the former of which the parasite would continue to exist without causing any harm to the host, but at the same time serving as a reservoir from which a fresh epidemic may start under favourable conditions.

SARCODINA

192. Amœba-like Parasites.—Several Amœbæ are known to live in the human body, at least one of which produces very serious pathological symptoms These are —

Entamœba histolytica and *E coli,* which live in the intestine, *E gingivalis* in the mouth, *Endolimax nana, Iodamœba williamsi* and *Dientamœba fragilis* Of these, the first, viz , *E histolytica* is the cause of amœbic or tropical dysentery

193. Entamœba histolytica.—(Fig 60) This is a small amœboid form, 20 to 30 μ ($\mu = 1/1000$ mm), with a clear ectoplasm and a granular endoplasm Within the body under normal conditions it moves about rapidly with a snail-like movement When removed to a glass-slide, however, it assumes a rounded form and throws out large blunt pseudopodia without actually moving The endoplasm contains ingested cells of the intestinal wall, red blood-corpuscles, etc. The presence of these distinguishes it from the closely related *E coli* which feeds on intestinal bacteria

In addition to binary fission encystment also takes place. Before encystment the size is reduced, the nucleus becoming comparatively larger, and rod-shaped **chromatoid bodies** and a **glycogen-vacuole** are formed The organism rounds itself up and a thin membranous protective cyst is formed In the encysted condition the nucleus divides twice in succession so that the organism contains 4 nuclei. The cysts pass out along with the faecal matter and under favourable conditions they retain their vitality for 4 or 5 weeks. They may contaminate drinking water, vegetables or other food and infect fresh hosts.

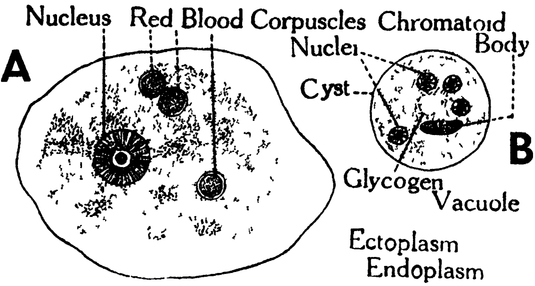

Fig 60 *Entamoeba histolytica* **A,** a vegetative individual, stained, **B,** a cyst with four nuclei (× 1200) (Altered from Chandler)

Only about 10% of infected persons show symptoms of any disease, the others serving as carriers and disseminating the parasite, a circumstance which makes its eradication almost impossible

Prevention of infection consists of the sanitary disposal of the faeces, protection of water-supplies from pollution and avoidance of uncooked vegetables or their sterilization

The parasite lives in the intestine and colon and burrows into the sub-mucous connective tissue causing bleeding The stools therefore contain blood and mucus along with swarms of amœbae There is griping pain for a few days The parasite may reach the portal vessels and settle in the liver where it may encyst and pass into the bile-duct causing repeated infection

(75) Sketch Entamœba under the microscope

194. Other Entamœbae.—*E coli*, as the name indicates, is an occupant of the colon It is very similar to *E histolytica*, but is not pathogenic, feeding, as it does, only on intestinal bacteria

Entamœba gingivalis has lately come into prominence on account of its association with pus-pockets of pyorrhoea, in which it is almost always found It is not definitely established if it causes the formation of pockets into which bacteria, spirochaetes, etc , find their way or if it only invades the pockets made by the bacteria This parasite has been found in the crypts of infected tonsils, the inflammation of which may be aggravated mechanically by its presence.

MASTIGOPHORA (FLAGELLATA)

195. Intestinal Flagellates.—These are *Trichomonas* living in the mouth, large intestine and vagina, *Chilomastix*, *Embadomonas* and *Enteromonas* in the large intestine and *Giardia* in the small intestine of man.

All except *Trichomonas* secrete a cyst The unencysted protozoans cannot infect a fresh host as they cannot withstand the action of the acid in the stomach In all of them no intermediate host is present and infection is direct

Trichomonas (Fig 61) is a rounded or pear-shaped form, with a characteristic structure There are 3, 4 or 5 long slender anterior flagella, and along one side of the body there is an undulating membrane to the margin of which is attached another flagellum The end of the latter may or may not extend beyond the end of the membrane. The body is supported by a stiffened axial rod or **axostyle** which frequently projects at the posterior end. The nucleus is round or oval, in the anterior part of the body There is a cytostome opposite the undulating membrane Intestinal forms have food-vacuoles containing ingested particles while others lack them

The organism moves along by the synchronous beating of the clustered flaggella of the anterior end There are several species, of which *T hominis* is the most important pathogenic form.

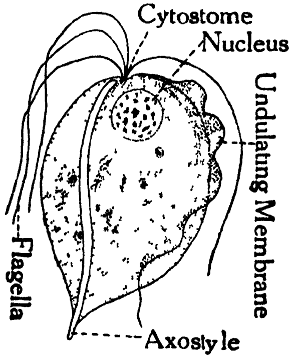

Fig 61 *Trichomonas hominis*, (x 2600) (Altered from Chandler)

Trichomonas hominis is associated with a persistent type of diarrhoea in man with fetid yellow brown stools. *T. buccalis* is associated with advanced pyorrhoea *Giardia lamblia* (Fig 62) is especially found in children and is a very common parasite in the small intestine and duodenum causing a persistent infection lasting several years The organism is a bilaterally symmetrical one with 8 flagella, one pair at the the tip of the tail, the others arising from various points on the surface of the body Two slender axostyles are present Multiplication is by division. Encystment takes place with the formation of a thick oval cyst. *Giardia* causes symptoms of an intractable recurring diarrhoea with large quantities of yellow mucus in which are myriads of cysts.

The parasite has been found also in the gall-bladder under conditions of chronic digestive disorder accompanied by jaundice

(76) Sketch Trichomonas hominis under the microscope

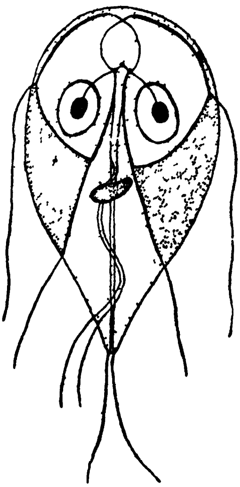

Fig 62 *Giardia lambia*, (× 3000) (Altered from Chandler)

196. Haemoflagellates.—Parasites of man included in this family, viz., the blood-flagellates are *Trypanosoma* and *Leishmania*

A typical Trypanosome (Fig 63) is an elongated spindle-shaped body, the more pointed end elongated into a flagellum The flagellum is continued back along the length of the body and is tracable to the basal granule from which it takes its origin A thin protoplasmic membrane connects the flagellum to the body The membrane and flagellum form a wavy line, and the locomotion of the parasite is evidently carried out by the undulating movements of the membrane and flagellum The cytoplasm is finely granular The nuclear apparatus consists of a large trophonucleus and a small kineto-nucleus which has the control of the locomotory activities of the organism Food and contractile vacuoles are absent

Multiplication is by longitudinal binary fission, in which the basal granule, kineto-nucleus, trophonucleus and the body take part in the order mentioned Syngamy has not been observed

197. Trypanosoma gambiense.—This is the parasite of sleeping sickness first discovered in the blood of a patient suspected of malaria in the neighbourhood of the river Gambia It invades the blood, lymph, cerebro-spinal fluid and even the brain substance, and is injected into the blood of man by the blood-sucking fly, *Glossina palpalis*, which is therefore the intermediate host When the blood is infected the parasites multiply rapidly, so that soon they become very numerous It is observed however that they cannot live in the blood for long A period of depression sets in and the vast majority die out except a comparatively few which are characterised by their short, stumpy bodies These alone are capable of surviving in the stomach of *Glossina* and infecting the fly, in which they speedily multiply and almost fill the intestine The parasites after a period of eight to eighteen days show several form-varieties, one of which is a peculiarly long variety with slender body These latter alone work their way to the salivary glands of the insect where they are found sixteen to thirty days after infection of the fly Here they cling to the lining of the gland by the flagella and multiply actively and become stouter in form like the ones which infected the fly Some are, however, distinguished by having the kineto-nucleus on the flagellar side of the trophonucleus and not at the blunt end of the body as in other stages This is called the *Crithidial* stage on account of the resemblance in the arrangement of the nuclear apparatus to the genus *Crithidia* The Crithidial forms do not thrive in the mammalian host when the fly bites a man, but the others serve to infect and start the life-cycle anew in the mammalian host

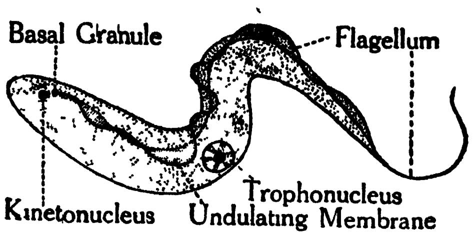

Fig . 63 *Trypanosoma gambiense*, (x 3200)
(Altered from Kerr)

A definite life-cycle thus is passed in the intermediate host Hence we speak of a *cyclical infection*, as against *direct infection* in which the parasite is directly transferred from one host to another.

(77) *Sketch Trypanosoma gambiense under the microscope*

198. Other Human Trypanosomes.—*Trypanosoma rhodesiense* causes sleeping sickness of a virulent type in Rhodesia and East Africa. It is transmitted by *Glossina morsitans*, the intermediate host also of *T brucii* Hence it is believed by some to be a variety of *T. brucii* which causes 'nagana' in cattle

T cruzi In this there is only cyclical infection. It is a common parasite in Brazil, and causes a disease known as 'Chagas' disease after the discoverer The intermediate host is a large blood-sucking bug. The malady is most frequent in children and is characterised by fever, enlarged glands, anæmia and disturbances of the nervous system. This parasite occurs also in several mammals like Armadilloes, Opposums and Rodents and can thrive in the blood of monkeys, guinea pigs, rats, etc., into which it has been inoculated.

199. Leishmania donovani (Fig. 64) is a terrible scourge in Assam, Bengal, Madras, the Yaungtse valley in China, Anglo-Egyptian Sudan, etc., in as much as it produces 'Kala Azar', "a disease mysterious in its origin, slow in its development and fearful in its results," with symptoms of typhoid, malaria or dysentery, and enlargement of spleen and liver The fever drops after several weeks only to recur several times until it gradually dwindles to a steady low fever and general wasting away, with the skin of a dark earthern colour (hence kala-azar or black fever) The mortality is large and incidence on an epidemic scale Though included among the blood-flagellates, *L donovani* is an intracellular parasite found in the spleen-cells of man as round little double-nucleated bodies called 'Leishman-Donovan' bodies which, when inocculated into a suitable culture medium, develop a flagellum and become free-swimming The intermediate host was formerly believed to be the bed bug, but this is doubted at the present day The normal host is probably the dog

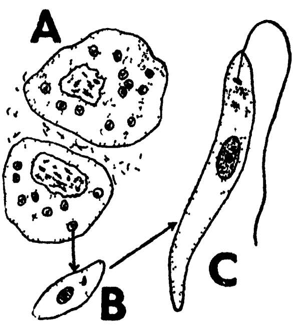

Fig 64 *Leishmania Donovani* **A**, two cells from the human spleen with "Leishman-Donovan bodies"; **B**, transitional form from artificial culture, **C**, flagellate free-swimming form, X 1000 (B and C, altered from Kerr)

(78) Sketch the Leishman-Donovan bodies under the high power of the microscope

200. Other Human Leishmanias.—*L tropica* causes oriental sore which is very common in N Africa to India Oriental sore is a local temporary sore on some exposed parts of the body *L tropica* is morphologically indistinguishable from *L donovanii* but infection by one does not confer immunity from the other Infection is probably by direct contact, a secondary host or transmitter, if present, being not known.

Leishmania braziliensis causes what is called Espundia or South American Leishmaniosis, a disease allied to oriental sore The sores are ulcerating and of very long duration (5 to 15 years) spreading over considerable areas and extending to the mucous membranes, often ending fatally. *L braziliensis* is also morphologically indistinguishable from the other two species cited above, but differ from them immunologically and clinically.

INTESTINAL CILIOPHORA

201. Balantidium Coli.—(Fig 65) Ciliate parasites abound in several vertebrates, especially herbivorous mammals They are mostly robbers of food and scavengers in their alimentary canal The only ciliate of importance in man is *Balantidium coli*, a large protozoan, 54 to 80 μ in length It is pathogenic and the symptoms resemble those of *Entamœba histolytica*, viz , ulceration of the large intestine, leading to diarrhoea or a severe type of dysentery ending fatally

(79) Sketch Balantidium coli under the microscope

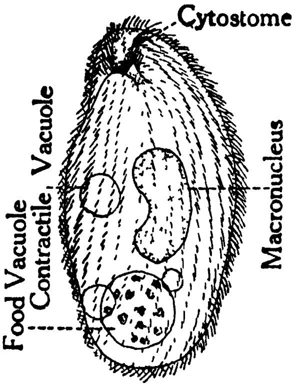

Fig 65 *Balantidium coli*, X 450 (Altered from Chandler)

SPOROZOA

202. Plasmodium and other Parasites.—The malarial parasite is the most important human sporozoan (See Chap 22)

A disease known as black water fever is prevalent in many parts of Africa and India, Malaya and East Indies, S E Europe and S E United States, exhibiting symptoms of jaundice, with tremendous destruction of red blood-corpuscles and secretion of hæmoglobin in urine It is still a mystery, and the causative organism is not yet known, though some people attribute it to a specific parasite related to the genus *Piroplasma* which causes black water fever in cattle

Sarcocystis, parasitic normally in the muscle of sheep, cattle and horses, has been rarely known to occur in man

203. Principal Phyla of Animals.—So far we have dealt with a vertebrate, viz , the frog, on the one hand and on the other with a few Protozoa, viz , *Amœba, Paramœcium, Euglena* and the malarial parasite. Between the highly organised tissued Vertebrata and the simple single-celled Protozoa range a number of animal groups of varying degrees of complexity. Zoologists have assigned them all to a few *phyla* or major sub-divisions of the animal kingdom. The principal phyla of animals are

Phylum Protozoa, e. g , *Amœba, Euglena, Paramoecium*, malarial parasite. Cytozoa

Phylum Porifera, the sponges. Parazoa

Phylum Coelenterata, e. g , *Hydra, Obelia*, jelly-fishes, corals.
Phylum Platyhelminthes, e g , liver-fluke, tape-worm
Phylum Nemathelminthes, e g., round worm.
Phylum Annelida, e g , earthworm, leech.
Inverte-brates Phylum Arthropoda, e. g , cockroach, prawn, scorpion.
Phylum Mollusca, viz., mussels, snails, cuttle-fishes. Metazoa (Histozoa)
Phylum Echinodermata, e g., starfish, sea urchin
Phylum Chordata
Sub-phylum Hemichorda
Sub-phylum Urochorda Primitive Chordates
Sub-phylum Cephalochorda

Verte-brates Sub phylum Craniata (Vertebrata), viz., fishes, amphibians, reptiles, birds and mammals.

In the chapters that follow, we propose to deal with examples of some of the phyla included under the familiar, but not strictly scientific, name Invertebrata

REVISION QUESTIONS

178 What is meant by 'direct' and 'cyclical' infection? Why is it that in the malarial parasite only cyclical infection takes place?

179 What do you mean by carriers? How do you account for their immunity? How do they constitute a danger to society?

180 What preventive measures would you adopt against malaria?

181 Name a few human diseases transmitted from man to man by insects. Name the insect in each case. Which of these diseases are caused by protozoan parasites?

182 *Leishmania donovani* assumes a flagellate free-swimming phase when grown in a suitable culture. What light does this throw on the probable evolution of its parasitism?

183. What is the effect of parasitism upon the parasite and upon the host?

CHAPTER 24

PHYLUM COELENTERATA—THE ZOOPHYTE, OBELIA—HYDRA VULGARIS, A FRESH-WATER POLYP—CHARACTERS AND CLASSIFICATION OF COELENTERATA

Material for Study A tube of Obelia zoophyte and of Obelia medusae, micro-slides of the same, live Hydrae collected from a pond, micro-slides of t s and l s *Hydra* and of t s testis and t s ovary of *Hydra*

OBELIA

204. Habitat and General Appearance.—*Obelia* is a marine organism, which exhibits a sexual and an asexual phase in its life-history. The asexual form is attached to see-weeds, wooden piles of piers, etc., as a delicate, whitish or light brown, almost fur-like growth, while the sexual form is free-swimming and collected by means of a tow-net from the surface waters of the sea

Remove some of the contents of the tube containing the zoophyte into a watch-glass Examine carefully with the help of a lens. Note the general plant-like appearance (hence, zoophyte) and the creeping stem or rooted portion called **hydrorhiza** from which arise vertical stems or **axes** upon which are arranged alternately on the two sides a number of **polyps** or hydroids. Each stem may be highly branching, in which case the older polyps will be borne on the branches In the axils of the older polyps are placed cylindrical bodies called **blastostyles.**

Practical work

The medusae are best examined with the help of the microscope They are small, almost transparent and disc-like bodies as seen by the naked eye.

205. The Stem.—(Fig 65, A) Examine the micro-slide of the zoophyte or a small stem cut off from the zoophyte in the tube under the microscope The stem is then seen to consist of a brownish horny **perisarc** or outer portion, inside which lies th **coenosarc** or living tissue (of course, now dead) The perisarc is merely a secretion of the coenosarc, and serves as a protective external skeleton for it It consists of two concentric layers of cells, viz, the outer **ectoderm** and the inner **endoderm.** (See Sect. 148.) Within the endoderm is a tubular cavity, the **coelenteron.** (Figs. 66, A, B and 68, A).

Practical work

This arrangement of parts is seen throughout the stem and the hydrorhiza. Each of the two layers, ectoderm and endoderm, consists of but one row of cells. The two rows are cemented together by a gelatinous secretion of them called **mesogloea.**

Practical work

206. The Polyp.—(Fig. 65, B) The polyps are also made of perisarc and coenosarc. The perisarc is dilated to form a wine-glass-shaped **hydrotheca.** The coenosarc consists of the same two layers as in the stem, viz , ectoderm and endoderm with mosogloea between Like the hydrotheca, the coenosarcal portion is also dilated and at the terminal spout-like portion opens the **mouth.** This spout or **hypostome** is surrounded by a circlet of about twentyfour **tentacles.** They consist of an outer layer of ectoderm with a rod of endoderm cells packed inside end to end, and highly vacuolated The mouth opens into a space called the coelenteron lined by endoderm and continuous through the stalk of the polyp with the coelenteron of the stem The base of each polyp rests on a circular **shelf** arising from the inner side of the hydrotheca, near its narrow end. The polyp-body is continued into the general coeonosarc through an aperture in this shelf. The stalk of the polyp is marked by a few annulations which give it a segmented appearance, the constrictions, however, being confined to the perisarc.

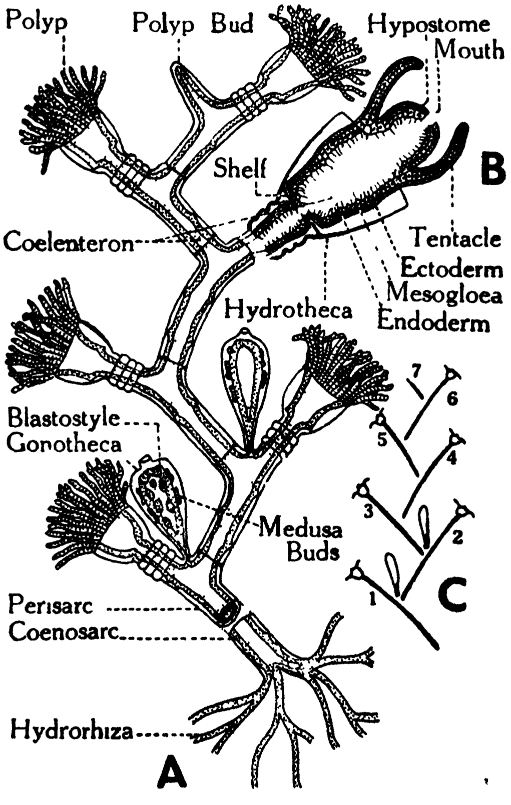

Fig 66 *Obelia* **A**, a small branch of a colony (× about 10), **B**, a single polyp in longitudinal section (× about 20), **C**, diagram showing the order of succession of polyps and mode of budding

The ectoderm of the polyp is made up of a row of large conical cells with their bases outwards. Between their narrow inner ends are clumps of small rounded **interstitial cells** (Fig 70, B) and occasionally large branched **nerve cells.** The tentacles and manubrium contain in addition a layer of unstriped **muscle fibres** between the ectoderm and mesogloea arranged longitudinally. These serve for the contraction of the tentacles and manubrium. Embedded in the ectoderm are also numerous clear ovoid bodies called **nematocysts** or stinging capsules.

207. A Nematocyst.—(Fig 67) Each nematocyst is a capsule developed inside an interstitial cell called a **cnidoblast.** Inside each capsule is a large space full of fluid. The outer end of the capsule is invaginated into the interior and forms a long spirally coiled tube floating in the fluid. When the nematocyst is fully formed the cnidoblast migrates to the outside and lodges itself in between the ectoderm cells. At one point on its exposed surface the cnidoblast projects out as a delicate protoplasmic hair called the **cnidocil** or trigger-hair When the cnidocil is touched by a small organism, the entire cnidoblast undergoes a sudden contraction This results in the nematocyst being pressed and the coiled tube inside everted violently and discharged rapidly to the outside. In thus being discharged, the portion that comes out first is, naturally, not the tip, but the basal portion of the tube. This end carries a few sharp blades which cut into the body of the prey and make a wound into which the finer portion of the tube can easily penetrate. The fluid injected into the body causes a numbing effect upon the prey, which is now drawn towards the mouth by the tentacle.

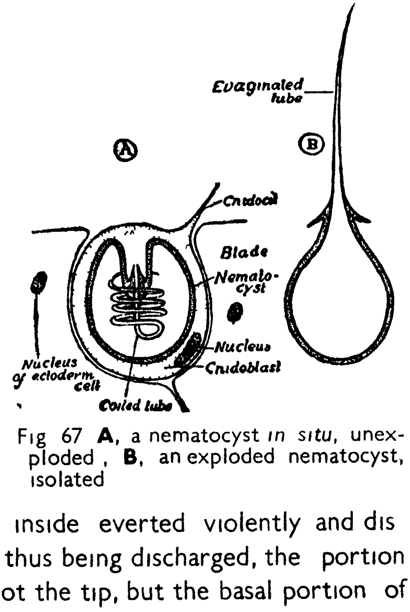

Fig 67 **A**, a nematocyst *in situ*, unexploded , **B**, an exploded nematocyst, isolated

Nematocysts are most numerous on the tentacle and hypostome. On the former they are arranged in annular rows.

208. Blastostyle.—Examine a blastostyle (Fig 66, A) placed in the angle between a polyp and the stem It is seen to be enclosed in fibres and can be traced on through other fibres to the muscle cells Thus there is a definite afferent and efferent path going to and proceeding from the nerve centres or ganglion cells.

Marginal sense organs called **statocysts** are easily seen in the slide, one at the base of each ad-radial tentacle (Fig. 68, A and B) They are therefore eight in number, two for each quadrant of the medusa Each statocyst consists of a rounded vesicle situated on the lower side of the swollen base of the tentacle. It has a covering of ectoderm cells. Lining its cavity are extremely thin cells, one of which, however, is very large and projects into the cavity and secretes a large calcareous **statolith,** and rests upon sensory hairs arising from the lining cells. In the normal vertical position of the animal, the statolith weighs down upon the sensory hairs, but when the medusa tilts to one side, the strain is altered and an impulse generated, which causes the animal to right itself The function of the statocyst is therefore to enable the organism to maintain its equilibrium.

211. Sexual Reproduction.—The medusa, as already mentioned, is the sexual phase in the life-cycle of *Obelia* The **gonads** are four pouch-like organs hanging from the four radial canals (and therefore per-radial) into the sub-umbrellar cavity. They are easily seen in the slide. They arise as outgrowths from the radial canals which pushing the ventral mesogloea and ectoderm before them come to project on the sub-umbrellar side Obelia is diœcious, that is, the sexes are separate The mature germ cells burst through the ectoderm to the water, where fertilisation takes place Segmentation follows, and results in a blastula and later a gastrula The latter hatches out as a free-swimming **planula** larva, so called from its slightly flattened shape Later, it attaches itself to the substratum by the end opposite the blastopore (which, in the free-swimming stage, was anterior), develops tentacles around the mouth (blastopore) and becomes a polyp, from which a whole colony arises by growth and budding.

(81) Sketch the medusa under the microscope.

212. Vegetative Growth or Asexual Reproduction.—From the side of this first polyp (Fig 66, C, 1) arises, in course of time, a bud which becomes polyp 2. In its turn it gives rise to polyp 3 on the same side as I—and so on till a large colony is established. Blastostyles and medusa-buds arise in due course The zig-zag stem of the colony is thus formed by the basal portions of the successive polyps put end to end

213. Polyp and Medusa Compared.—Though so different in appearance and function, the polyp and medusa are built on the same fundamental plan Both have the same cell-layers with the mesogloea between them The coelenteron or gastric cavity in both is lined by endoderm, and it has but a single opening to the outside The tentacles fringe the margin of the oral cone or the sub-umbrella as. the case may be

The differences between the two are

TABLE 7

POLYP AND MEDUSA CONTRASTED

POLYP	MEDUSA
1 Primary axis long and body tubular	Primary axis short and body disc-shaped
2 Oral and aboral endoderms distinct	These form a lamella
3 Gastro-vascular cavity deep and large	It is shallow and small
4. No radial and circular canals	These are present
5. Mesogloea thin, supported by perisarc	Mesogloea thick and supporting, no perisarc
6 Tentacles without sense organs.	Marginal sense organs are present
7 Poorly developed nervous system	Well developed with nerve ring and ganglion-cells
8 Sessile	Free-swimming
9 Reproduces asexually and gives rise to colony and medusae	Reproduces sexually, and gives rise to the asexual form

214. Alternation of Generations (Metagenesis).—Obelia furnishes an example of the phenomenon of alternation of generations met with in several groups of animals in which a *sexual form alternates with an asexual* As a matter of fact, a sexual generation alternates with a number of asexual gemmations (buddings) as is seen from the formula . Medusa—Zygote—Polyp—Polyp—Polyp—Blastostyle—Medusa, The word metagenesis signifies this particular kind of alternation of generation and is therefore more applicable to the reproduction of Obelia It literally means postponed sexual generation.

Closely allied to metagenesis is the phenomenon of **polymorphism.** We speak of a species as polymorphic when it consists of several kinds of individuals In Obelia, we have polyps or the feeding and nutritive individuals, the blastostyles or the individuals which bud off the medusae and finally the medusae themselves which are the free-swimming sexual individuals.

The polyp colony being sedentary is unable to disseminate the species even if it were provided with reproductive organs. This disadvantage of a fixed life is made up for by the medusae, which, swimming away from the parent colony, help to establish new ones far and wide

HYDRA VULGARIS, THE FRESH-WATER POLYP

215. Habitat and External Features.—*Hydra* is a fresh-water organism, very commonly found in stagnant pools in which water weeds are plentiful If bits of water weed are transferred into a few test-tubes filled with water from the pond itself, and allowed to stand for a while, the Hydrae, if any, would expand fully meanwhile, and can be seen easily by holding the test-tubes against the light It may be difficult at first to spot out the hydrae, but when one is made out, the chances are that there will be several more They will be seen sticking to the leaves or the stem of the plant or to the sides of the tube, and are made out by their cylindrical body crowned with about five tentacles

Practical work

Transfer a few specimens into a watch glass with water and examine them under the low power of the microscope or with a strong lens (Fig 69, A, and B) Note the cylindrical shape of the body The attached end is slightly narrower than the rest of the body, while the free end bearing the **tentacles** is slightly thicker Inside the circlet of tentacles is an oral cone called the **hypostome,** in the centre of which is the **mouth.** The attached end is blind

Note the swaying movements of the body and of the tentacles. What purpose is served by these movements? Touch one of the Hydrae with the point of a needle. The body contracts *suddenly* into a little round lump, with the tentacles as five little knobs on it (Fig. 69, C) Watch the animal as it expands *slowly.*

(81) Sketch the Hydra fully extended and in various stages of contraction.

216. Feeding.— Hydra feeds on water-fleas (minute Crustacea, plentiful in ponds, etc , see Sect 337), and if we watch long enough we may see the little polyp feeding As soon as a water-flea touches one of the tentacles, it suddenly stops as if paralysed and remains fixed to the tentacle The tentacle is gradually contracted so as to bring the crustacean to the mouth The other tentacles help to shove the food into the mouth, which expands considerably to receive the prey After swallowing, the water-flea lies inside the **coelenteron** causing the body to bulge by its presence The digestion takes place in the coelenteron and the indigestible waste is thrown out at the mouth, since there is no anus In a *Hydra* which has just fed, we can see the whole extent of the coelenteron to advantage

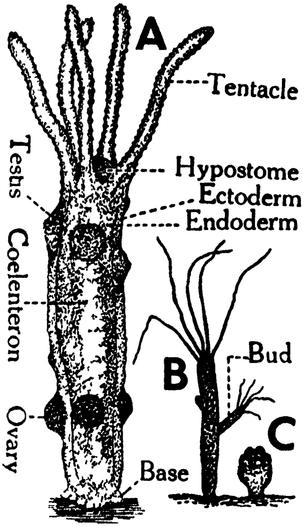

Fig 69 *Hydra* **A,** an entire sexually mature specimen under the microscope (X about 10) , **B,** a specimen with two buds , **C,** a specimen fully contracted

217. Locomotion.—Though usually fixed by the blind end of the body, *Hydra* is capable of moving about to a certain extent. These movements can be observed in a living specimen, patiently watched for a long time The cells of the base of the body are capable of pseudopodial movements by means of which the polyp can slowly glide on its substratum Sometimes the tentacles become attached to the substratum, the base is then released and drawn towards the tentacles and attached to a new spot. The body now expands, the tentacles leave their grip of the substratum and are attached to a new spot, and the whole process is repeated, the movements resembling in general the looping movements of a caterpillar *Hydra* sometimes somersaults, resulting in fairly rapid progression from place to

Sometimes both the organs are seen in the same section, since Hydra is hermaphrodite or bisexual The **testis** will be seen in the form of a conical or rounded prominence covered by modified ectodermal epithelium The **ovaries** are developed nearer the base of the polyp in most specimens An ovary, like the testis, is a rounded prominence covered by ectoderm cells with interstitial cells within The large cell centrally placed in the ovary is the ovum

In the case of the testis the heap of interstitial cells rapidly divide and give rise to a large number of sperms On the other hand, the interstitial cells of the ovary at first increase in number by multiplication, but soon one of them, destined to become the ovum, puts forth pseudopodia like an *Amoeba* and ingests the others. Yolk-granules are also formed in it Eventually it becomes rounded and a process of maturation takes place in which the nucleus divides twice in succession and polar bodies are given off The large ovum is now exposed owing to the rupture of the covering ectoderm, and is ready to be fertilised by a sperm

(83) Sketch the sections through the testis and the ovary

222. Reproduction.—*Hydra*, like *Obelia*, reproduces both sexually and asexually When food is abundant **asexual** reproduction takes place The bodywall pushes out at a point about the middle of the length of the body—ectoderm, mesogloea and endoderm being included in the out-pushing—as a small hollow **bud** (Fig 69, B) This gradually grows and becomes a cylindrical outgrowth A mouth opens at the tip of the bud into the coelenteron which is continuous with that of the parent, and tentacles soon make their appearance round the mouth When the features of a Hydra have been fully formed, the bud gets detached from the parent Several generations may thus be formed in the same season, and the same individual may give rise to several buds in succession It is not unusual to see a specimen bearing more than one bud Secondary buds are said to be sometimes formed, giving rise to an incipient colony

Hydra can regenerate lost parts to a considerable extent. A specimen cut up into bits will give rise to as many small specimens, one from each bit Longitudinal fission beginning at the mouth end has also been observed in some species.

Sexual reproduction persumably takes place when unfavourable conditions threaten and the water is about to dry up, for each ovum soon after fertilisation secretes a hard resistent protective coat inside which further development takes place. The embryo thus protected drops away from the parent Hydra, and is capable of persisting through cold or drought until at last favourable conditions reappear, when the embryo escapes from the cyst and reaches the adult stage. In the encysted condition the embryo may be carried away by water or air to distant places and the species thus be disseminated

223. Characters of Coelenterata.—In *Hydra* and *Obelia*, two genera of this phylum, we note that the body is radially symmetrical, and made up of two cell-layers, viz, ectoderm and endoderm, cemented together by a structureless layer, mesogloea. There is only a single cavity inside the body, that is, the coelenteron, whether it be simple as in the polyps or branched as in the medusæ, and this cavity is lined by endoderm. It opens to the outside by a mouth, which serves for taking food and for letting out the fæcal matter. The zoophytes, the jelly-fishes, sea-anemones and corals belong to this phylum. ✓

224. Classification of Coelenterata.—The Coelenterata are classified into three classes —

i Class Hydrozoa. Coelenterata with a simple coelenteron There is typically an asexual colonial hydroid stage alternating with a sexual medusoid stage in most genera Gonads typically per-radia and the germ-cells are of ectodermal origin. The medusæ are characterised by a velum Examples —*Hydra*, the fresh-water polyp; *H. viridis* and *H. fusca* exhibit symbiosis, *Obelia*, *Cunina* has no polyp stage, *Stylaster* produces a hard coral; *Halistemma* is a pelagic colonial form with a float.

ii. Class Scyphozoa. Coelenterata in which the adult is always a medusoid with a complex coelenteron. Gonads inter- or ad-radial and of endodermal origin. Oral tentacles are present in addition to the marginal ones. All are marine, pelagic and of much larger size than Hydrozoan medusæ Examples.—*Chrysaora*, the common Indian jelly-fish, *Aurelia*.

iii Class Anthozoa (Actinozoa).—Coelenterata which exhibit only a polyp or hydroid stage, solitary or colonial, with a well-soft and fragile and covered over with a coat of mucus. At the anterior end dorsally are a pair of **eyes** marked by two black spots. The **mouth** opens on the ventral side behind the middle of the body. Further back near the hind end is the cloacal or **genital aperture.**

(85) Sketch the external features of a Planarian

226. Internal Anatomy.—(Fig. 71, B) The mouth leads into a short, thick-walled tube called the **pharynx,** capable of being thrust out through the mouth to a considerable extent In the retracted condition it lies in a muscular sheath. It leads into an **intestine** which at once divides into three main branches, an anterior running headwards and two posterior running one on each side of the pharynx-sheath. The three together resemble a tuning fork, the anterior being the handle and the posterior, the prongs. Each of these main branches gives off numerous small branches which in their turn rebranch so as to give rise to a highly ramifying system. The food is thus brought into close contact with every part of the body and makes a vascular system for carrying the food to the various parts of the body entirely unnecessary There is no anus

There is a well-developed **excretory system,** consisting of two main longitudinally placed, but highly convoluted trunks which open on the dorsal surface by a number of paired external openings The two lateral tubes are connected together by a transverse tube in the head region Each lateral tube branches into smaller ones, and each of these again into fine capillaries many of which end in flame-cells A **flame-cell** (Fig 71, C) is a tubular cell clubbed at the free end which carries the nucleus The narrow handle is tubular and the tube is in communication with the general system of excretory tubes In the blind end of the tube lies a bunch of long cilia arising from the body of the cell. When a live specimen is examined under the high power of the microscope, it is seen that the cilia exhibit a flickering movement reminding one of a candle-flame, whence the name flame cell The function of the flame-cells is to drain away the excess of water from the parenchyma of the body. The vibration of the cilia causes a current of water to flow from the flame-cells towards the excretory tubes and this causes in turn an indraught of water from the parenchyma into the soft protoplasm of the flame-cells In other words there is a constant current of water coming into the body through the skin and passed out at the excretory openings after infiltrating through the body. Thus we speak of a system of **water vessels,** which wash away the excretory waste and may, at the same time, subserve a **respiratory** function

The **nervous system** consists of well developed nerve centres and nerves, unlike what we have seen in the Coelenterata The diffuse elements of that group of animals, here take the form of a **brain** at the anterior end produced backwards into a pair of longitudinal **nerve cords.** Numerous transverse nerves or commissures from the longitudinal nerves anastomose and form a plexus. The anterior end of the body is well enervated and is highly sensitive

(86) Sketch the whole mount of Planaria under the microscope

227. Sexual Reproduction.—(Fig 71, B) *Planaria* is hermaphrodite Numerous spherical **testes** are placed along the two margins of the body The sperms pass out from them into small vasa efferentia and reach a **vas deferens.** The two vasa deferentia from the two sides unite in the middle line posteriorly The common duct thus formed traverses a protrusible muscular organ, the **penis,** and opens into the **cloaca** or common male and female tract A **seminal vesicle** in which the sperms are stored away lies at the base of the **penis.**

There are two **ovaries** situated at the anterior end, each connected with an elongated **oviduct** which receives a number of vitelline ducts from **vitelline glands** along its whole length The two oviducts unite posteriorly to form a short common median oviduct opening into the cloaca The eggs are stored in the **uterus,** a median rounded chamber, also opening into the **cloaca.** In addition to these is a thick-walled muscular body of unknown function, called the **muscular sac.** The eggs as they pass down the oviduct are coated with yolk-laden cells and are fertilised in the uterus where sperms from another individual are received in copulation Several fertilized eggs are packed up in a cocoon There is no larva, but the embryo hatches out as a tiny worm like the parent

228. Asexual Reproduction.—Some species of *Planaria* reproduce asexually. Fission takes place in a transverse plane behind the pharynx and several potential segments or individuals may be present in the portion behind the plane of fission The power of **regeneration** of lost parts is very considerable Any segment, anterior, middle or posterior, cut off from the body can regenerate the entire animal.

229. Transverse Section.—(Fig. 72) When examined under the microscope, the section of the body reveals a striking advance in organisation upon the Coelenterata. There is a ciliated **ectoderm** of columnar cells covering the entire body resting on a **basement membrane.** The intestine and its branches are lined by a layer of columnar cells, viz., the **endoderm.** Between the two, however, is a layer of tissue which forms a definite third cell-layer or **mesoderm.** This third layer includes several elements and forms a connective tissue between the various organs of the body, and on account of its loose texture made up of vacuolated cells, connective tissue and muscle fibres, is comprehensively called the **pa[illegible]hyma.** Outside the parenchyma and immediately inside the ectoderm or epidermis is a double layer of **muscles,** the outer circular and the inner longitudinal Dorso-ventral muscle strands may also appear in the section In addition to these we note peculiar rod-shaped refractile bodies of unknown function called **rhabdites** formed in the deeper portions of the parenchyma in special rhabdite cells The rhabdites are extruded through the parenchyma into the ectoderm in which also they may be found in numbers Several of the internal organs may also be cut in the section depending upon the particular region of the body through which the section passes

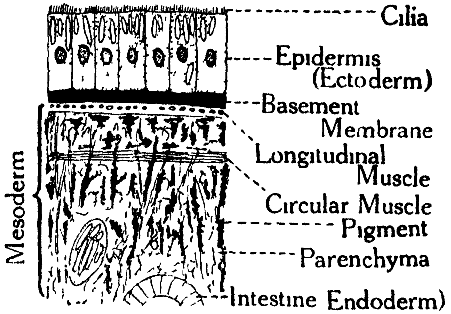

Fig 72 Portion of t s of a Blanarian to show histology (For Circular read Longitudinal and *vice versa*)

(87) Sketch the slide of t s of Planaria under the microscope

230. Structural Advancement.—It is clear from the foregoing description that *Planaria* is more highly organised than the Coelenterata. The digestive system is more complex as are also the reproductory and muscular systems The nervous system is concentrated into a definite brain and nerves The excretory functions are carried out by a special system entirely absent in the Coelenterata *Planaria* is free moving with a strictly bilateral symmetry, in which dorsal and ventral sides and anterior and posterior ends are well marked.

FASCIOLA HEPATICA, THE LIVER-FLUKE

231. External Features.—*Fasciola (Distomum) hepatica* is a parasitic Platyhelminth worm, popularly called the liver-fluke, and lives inside the bile-ducts of sheep and less frequently of cows, pigs, etc. It is the cause of the disease known as 'liver rot,' responsible for immense loss to sheep reared in marshy districts. The nature of the country, it will be seen later, has an important bearing upon the larval life of the fluke and hence on its incidence.

A liver-fluke is shaped more or less like a leaf (Fig 73) The body is very flat so that a large specimen over an inch in length can be studied under the microscope as a transparent object The surface of the body is covered by a thin, but tough **cuticle** with backwardly projecting spines allowing of movement in the forward direction only. The **mouth** is placed inside an **oral sucker** which marks the anterior end of the body This sucker is on an eminence projecting from the general outline. Immediately behind this eminence on one of the flat sides is the **ventral sucker,** an organ for adhering to the inner wall of the bile duct This sucker marks the ventral side.

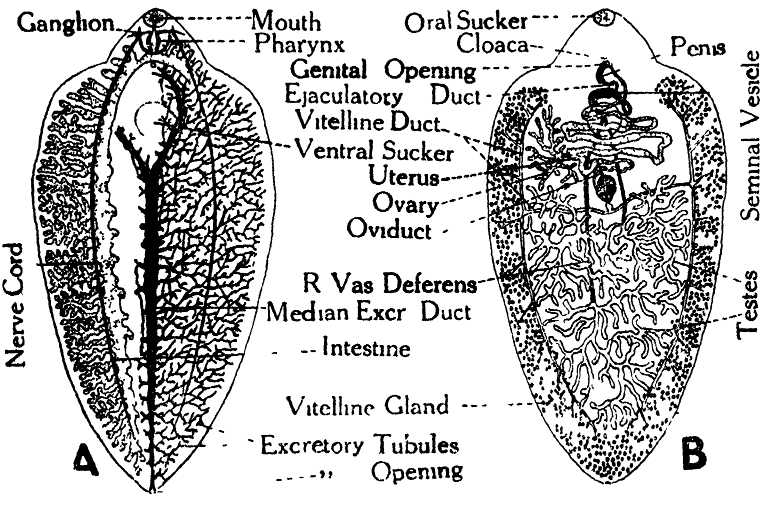

Fig 73 *Fasciola hepatica* **A**, semidiagrammatic ventral view showing the alimentary, excretory and nervous systems, **B**, a similar view showing the reproductory organs

(88) Sketch the external features of the liver-fluke.

235. Larval History.—(Fig. 74) If an egg happens to fall into water a larva called **miracidium** emerges from it after a period of embryonic development extending between three to six weeks, pushing aside the little lid of the egg, and escapes into the water It is about 0 12 mm. long and looks much like a *Paramæcium* on account of a uniform coat of cilia by the help of which it swims about actively At the front end is a conical proboscis capable of being retracted and thrust out A little behind is a nerve-ganglion and embedded in it is an *x*-shaped eye-spot There is also an imperfectly developed intestine and a pair of flame-cells with the ducts opening on the surface In the parenchyma are also numerous "germ cells" The larva after a period of about 8 hours of free-swimming life seeks out a host, which is a small fresh-water snail and dies if it fails in its search If it does find a snail, it attaches itself to its soft skin by the proboscis and boring its way into the body cavity eventually takes up its position in the large blood sinuses in the roof of the lung In this position it changes its shape, the nerve ganglion and eye degenerate and the entire larva becomes converted into a bag-like structure called **sporocyst** containing only germ cells in the form of round little clumps. These undergo repeated division and elongate gradually into the form of the next larval stage known as **redia,** marked by two short humps projecting from the hinder end of the body, one on each side It has a mouth opening into a muscular pharynx and a short blind intestine reminding one of the alimentary canal of the adult Between the gut and body wall is a parenchyma filled with clumps of germ cells and near the head end is a single reproductory opening The fully formed rediæ escape from the remnants of the sporocyst and wander inside the body of the snail until they reach the liver. Here the germ cells as a rule develop into a new generation of rediæ.

The germ cells of these **secondary radiae** develop into somewhat tadpole-shaped larvæ, with an ellipsoidal body and a tail, and called **cercariæ.** The latter can swim by means of their tails. Their general organisation is like that of the adult, with the anterior and ventral suckers, a U-shaped alimentary canal with the mouth-opening in the anterior sucker and a nerve ring around the pharynx. On each side of the median line there is a mass of gland-cells The interspaces between the organs is filled up by the characteristic parenchyma The cercariae now leave the body of the snail and pass out into the water.

The tails are lost The young flukes creep up the blades of grass and a cyst is formed around each from the secretion of the unicellular glands. Some development takes place in this position, but is not completed unless the blade of grass with the encysted cercaria is eaten by a sheep Should this happen, the cyst dissolves in the stomach of the sheep and the young fluke makes its way up the duodenum and into the bile duct where the adult condition is gradually reached.

(90) Sketch the eggs and larvae under the microscope

TAENIA SOLIUM THE PORK TAPE-WORM OF MAN

236. External Features.—*Taenia* has several species of which *Taenia solium* (6 to 9 feet long) is a common one infesting man in pork eating countries The adult worm found in the intestine of man, is attached to the wall by one end of its long tape-like body The attached end is narrow, while the free end is broader. The attached end is marked by a terminal knob, the head or **scolex** (Fig 75, A) It is pear-shaped and bears at its proximal end a rounded prominence, the **rostellum,** bearing around its base a double row of about twentyeight recurved and pointed **hooks.** The rostellum can be slightly protruded and retracted, and is evidently an organ of attachment. Four cup-shaped **suckers**, also organs of adhesion project around the sides of the scolex. The narrow portion behind the head may be termed the neck The part following is the body or **strobila.** It consists of a large number of segments or **proglottides.** In a fully grown worm there may be as many as over 800 proglottides. These are narrow and short next the neck region and become broader and longer (Fig 75, B) as they pass towards the free end Those at the free end are also older and riper than those in front. They break loose and pass out along with the faeces of man, and contain the ripe eggs inside Newer and newer segments are at the same time added in the region between the neck and the first proglottis

(91) Sketch the scolex of T solium under the low power of the microscope

There is no digestive system, but the excretory and nervous systems are fully developed, and each proglottis bears a full complement of all the male and female organs, not unlike what we have seen in the Planarian and the liver-fluke.

237. Internal Anatomy.—The **excretory system** consists of a net-work of fine canals in the parenchyma bearing flame-cells. The system of canals drain into a pair of **longitudinal excretory canals** one on each side of the body (Fig. 75, C). The two canals are connected by a transverse canal at the hinder margin of each proglottis, so that the entire system resembles a ladder. In the last segment, the transverse canal opens into a pulsatile **caudal vesicle** communicating with the outside When that segment drops off the longitudinal canals open directly to the outside

There are two, not well defined, ganglia, united by a broad transverse commissure in the head region. Slender **nerves** pass from this to the suckers and two **longitudinal nerves** run backwards through all the proglottides to the posterior end of the body The longitudinal nerves are placed external to the excretory canals. There are numerous irregular **commissures** connecting the two longitudinal trunks.

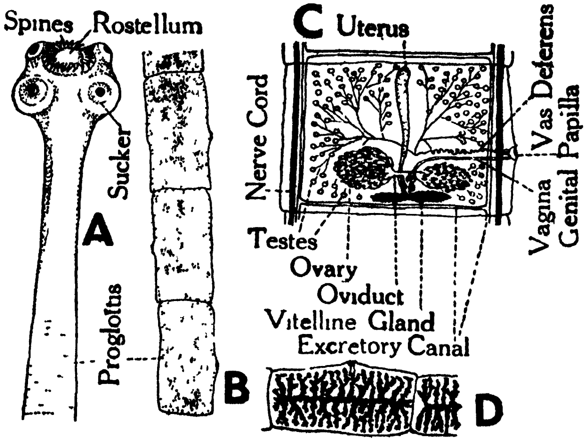

Fig 75 *Taenia solium* **A**, scolex with neck region and incipient proglottides, (× 5) , **B**, a length of the worm from near the free end, showing the alternate arrangement of the genital papillae, (× 1), **C**, a ripe proglottis from behind the middle of length of the worm showing the reproductory organs, (× 4), **D**, a ripe proglottis with the hypertrophied branching uterus (dark), (× 1).

238. A Single Proglottis.—(Fig. 75, C) Each proglottis is marked, not only by its anterior and posterior margins, but also by the **genital papilla** placed about the middle of its edge. The papillae of the various segments alternate regularly on the two sides. In addition to portions of the nervous and excretory organs, already described, the proglottis contains the reproductory organs, fully developed in the posterior segments

The male organs appear first, followed later by the female organs. A segment about the middle of the length of the body shows both fully developed The **testes** are numerous small spherical bodies scattered in the parenchyma The vasa efferentia unite to form a transverse **vas deferens** which opens into the common **cloaca.** The sperms are stored in the vas deferens near its outer end. The cloaca is marked by the genital papilla of the segment.

The female organs are more complicated. There is a bilobed **ovary** placed near the posterior margin of the segment. It consists of a number of lobules The eggs pass down into a median **oviduct.** A **vitelline gland,** consisting of a number of minute lobules and placed behind the ovary, sends forward a yolk-duct which joins the oviduct. Where the oviduct and yolk-duct unite is a **shell-gland.** The portion formed by the confluence of the oviduct, yolk-duct and shell-duct is continued forward as a wide median longitudinal **uterus** in which the fully formed eggs are stored away A narrow duct from the cloaca called the **vagina** passes inwards and joins the oviduct The sperms from another proglottis or another worm pass into the oviduct by way of the vagina and fertilise the ova in the oviduct The sperms are stored in a **seminal receptacle**, a dilation of the vagina near the oviduct The zygotes get themselves coated successively with a layer of yolk-cells and shell-substance before they pass into the uterus. When full of eggs the walls of the uterus distend and branch out laterally into a number of lobes Indeed a proglottis at the posterior end (Fig 75, D) is nothing more than a large uterus, all the other organs having undergone partial or complete atrophy, in proportion to its hypertrophy

(92) Sketch the proglottides from the middle and posterior end of the worm under the low power of the microscope or a strong lens

239. Life History.—(Fig. 76) As in the liver-fluke the life history is very complicated The ripe proglottides are detached from the tape-worm and passed out with the fæces. They remain alive for a time and show slight movements. Development has already set in and each embryo has assumed a round shape and six chitinoid hooks are developed in its body, whence it is known as the **hexacanth** embryo. In the event of the fæcal matter containing the ripe proglottides with the embryos being eaten by a pig, the most common intermediate host of the tape-worm, they get freed from their coverings and bore their way through the wall of the alimentary canal by the help of the hooks and reach the voluntary muscles of the pig. In this position they enlarge into round cysts or bladder-worms with a large fluid-filled cavity inside, and are known as *Cysticerci*, that of *T solium* being distinguished as *Cysticercus cellulosæ* One side of the cyst is invaginated into the hollow and at the bottom of the invagination are developed the hooks and suckers characteristic of the adult The entire invagination is now everted in such a manner as to bring the scolex, now fully formed, to the outside The embryo now resembles a bladder from the surface of which projects the scolex and neck of a tape-worm. A pig may contain thousands of cysticercus larvæ which are small round bodies, the size of a pea If pork infested with them is eaten by man before they are killed by boiling sufficiently, the bladder-worms escape into the alimentary canal, throw off the bladders and attach themselves to the intestinal wall by their scolices The large number of proglottides are then formed and the adult phase is reached.

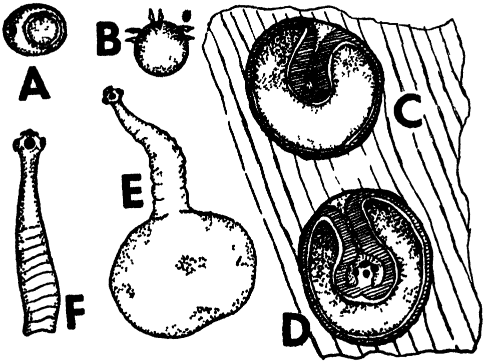

Fig 76 Life History of *Tænia solium* **A**, egg; **B**, Hexacanth larva, **C**, earlier and **D**, later stages of *Cysticercus cellulosæ* in muscle of pig, **E**, bladder-worm with scolex evaginated, **F**, young worm with the bladder thrown off

(93) Sketch the eggs, Hexacanth larva and Cysticercus under the microscope.

240. Characters of Platyhelminthes.—The examples studied show that the Platyhelminthes are bilaterally symmetrical animals with distinct dorsal and ventral sides. There are three cell-layers in the body, the epidermis or ectoderm, parenchyma or mesoderm and endoderm. In other words the flat-worms are **triploblastic.** There is typically an enteron or alimentary canal with but one external opening. A definite excretory system and nervous system are developed. There is no skeleton of any kind. The eggs are produced in vast numbers and are provided with a coating of yolk-cells for the nourishment of the embryo. Hermaphroditism is the rule Asexual reproduction may take place either in the adult or in the larval condition.

241. Classification.—Platyhelminthes are divided into three classes:

i. Class Turbellaria, free-living flat-worms with a ciliated, cellular epidermis Examples —*Convoluta,* harbours green symbiotic algæ; *Microstomum,* a small fresh-water form, capable of forming a chain of zooids by transverse fission *Planaria,* a common fresh-water form; *Bipalium,* terrestrial and characterised by a pair of lateral sensory lobes on the head, *Leptoplana,* marine

ii Class Trematoda, external or internal parasitic flat-worms without cilia or cellular epidermis The enteric cavity is well-developed. The body is flat One or more ventral suckers are always present Examples —*Polystomum* and *Tristomum,* ectoparasites with direct development, *Diplozoon,* ectoparasite of fish, with direct development; *Fasciola* and *Bilharzia,* endoparasites with complicated life-history, the latter diœcious

iii. Class Cestoda, endoparasitic flat-worms, devoid of cilia and digestive cavity, consisting of an attached scolex and a body divided into proglottides, or not so divided Examples —*Caryophyllaeus* and *Gyrocotyle,* the body not divided into proglottides, *Ligula* and *Tetrarhynchus,* few proglottides, *Bothriocephalus* and *Tænia,* with a large number of proglottides,

PARASITIC TREMATODA

242. Bilharzia hæmatobia.—This is a parasite found in the veins of man. Its life-history is marked by the presence of the same kind of larval forms as in *Fasciola.* It is peculiar in that, unlike other flat-worms, the sexes are separate. The flat body of the male, is as it were, rolled up so as to bring the two edges together and enclose a groove. For this reason, the worm enjoys the synonym *Schistosoma.* Inside the groove the much smaller and slenderer female is permanently lodged. The eggs are deposited in the small veins of the bladder. The shell is produced into a sharp spine by means of which a way is made for the eggs to pass out into the bladder and thence to the outside with the urine The eggs develop in fresh-water and a miracidium and other larval stages characteristic of the liver-fluke are undergone inside the body of a fresh-water snail The cercariæ are taken into the inside of the body not through the alimentary canal, but through the skin, and bore their way into the blood or lymph vessels and ultimately reaching the liver become sexually mature in that organ and migrate to their definitive abode, the veins of the mesentery.

There are several species of *Bilharzia* It is very common in Egypt and Africa generally It is also found in Tropical America, West Indies, China, Japan and the Philippines.

(94) Sketch the ova and the whole mount of Bilharzia under the microscope,

243. Diplozoon paradoxum.—This is a very interesting parasite of fish. In the adult condition the animals are paired or double, i. e., two young worms get permanently fused together into an X-shaped worm. The young is known as *Diporpa* and possesses a dorsal papilla and a ventral sucker. The generative organs are absent The Diporpæ attach themselves to the gills of fish and suck the branchial blood The junction of two diporpæ now takes place. The ventral sucker of one is affixed to the dorsal papilla of the other and fuses with it in such a manner that the vas deferens of the one animal is directly connected with the opening of the vagina of the other. The sex-organs develop only after the fusion has taken place. The eggs are attached by a long coiled thread to the gill-filaments of the host Development is direct with no larval stages or intermediate host as in *Fasciolæ*.

(95) Sketch the adult Diplozoon under the microscope

PARASITIC CESTODA OF MAN

244. Tænia saginata.—This is a human tape-worm reaching a length of 30 feet or more. It is distinguished from other human tape-worms (*T solium* and *Bothriocephalus latus*) by four very large suckers and the absence of spines on the scolex. The uterine branches in the shed proglottides are slender and very numerous. It is common in beef-eating countries since the intermediate host is the ox, in whose muscles the cysticercus stage (*Cysticercus bovis*) is passed. The infected muscle is called "measly beef" The cysticercus stage has been found occasionally in other herbivorous animals, such as antelopes, giraffes, etc

245. Bothriocephalus latus.—This is a large tape-worm reaching a length of thirty feet. The head is lance-shaped and there are no hooks. There are only two suckers in the form of longitudinal grooves. The reproductive openings are not along the margin, but on the flat side. The bladder-worm is found in fresh-water fish. Hence it is a common parasite of man in places where fish is largely eaten.

246. Taenia echinococcus.—The adult worm of this species is parasitic in the intestine of the dog, especially in countries where stock-raising is an important industry, such as Iceland, Australia and S America The adult is a microscopic worm compared to the others mentioned, and is not a human parasite, but the bladder-worm, which forms one of the hydatid cysts, reaching a diameter of up to seven inches, is occasionally found in the liver and other organs of man Owing to the large size of the bladder-worm, it is a formidable and dangerous parasite The bladder produces, not one, but several scolices as well as secondary bladders which may become freed into the cavity of the mother-cyst Several cysts may be found in the same host, as infection takes place mostly by the swallowing of the entire worm which escapes detection on account of its small size

(96) Sketch the scolices and a ripe proglottis of T. Saginata and Bothriocephalus latus.

MODIFICATIONS DUE TO PARASITISM

247. Modification in General Structure.—The flat-worms with the exception of the Turbellaria are parasitic. The change from the free-living to the parasitic mode of life brings with it profound modifications in the structure, development and life-history of the parasites. The Turbellarian condition may be taken as primitive and typical of the structure of the flat-worms as a phylum and the modifications that we note in the Trematoda and Cestoda are directly tracable to the particular kind of parasitic life which the animals lead.

In general we may distinguish two grades of parasitism among the flat-worms (as we have done also among Protozoa), ectoparasitism and endoparasitism. The **ectoparasites** are parasitic on the outer surface of other animals and form a transition from the non-parasitic to the endoparasitic condition, since they still retain their relation to the outer world which the endoparasites have entirely given up. The ectoparasitic Trematoda possess a well developed alimentary canal which is often richly branched The same may be said about other organ-systems also. But they possess special organs for adhesion like suckers (*Fasciola*), hooks (*Gyrodactylus*), adhesive papillæ supplementing the suckers (*Homalogaster*), tentacles in place of the anterior suckers (*Temnocephala*), marginal tentacles in addition to the suckers (*Actinodactylella*), etc A well developed sucking apparatus in the form of a muscular pharynx is present in the ectoparasitic as well as in the endoparasitic Trematoda Eyes are present and the sensory and locomotor apparatus are well developed The pigmentation of the body is also normal

The **endoparasites** are parasitic inside the digestive tract or other system of organs of the host They also possess well developed organs for attachment to the organ or part of the body in which they usually live In the more advanced Trematoda these are usually in the form of ventral suckers as already noted in the liver fluke In the Cestoda the 'head' is more usually radially symmetrical and the organs of adhesion are placed on it. The rest of the body simply hangs from this attachment Typically we get four suckers and a circlet of recurved hooks as in the case of the tape-worm, *Tænia*, the hooks being borne on a rostellum or retractile proboscis In *Bothriocephalus* there are no suckers and hooks, but only a pair of longitudinal grooves In many Cestodes, parasitic in fish, the head bears four prominent thin folded flaps or bothridia which are mobile and used as creeping organs rather than as organs of attachment. In *Tetrarhynchus* there are four very long and narrow rostella or proboscides covered with hooklets and capable of being retracted into sheaths. The alimentary canal is well developed in the endoparasitic Trematoda, but, as we have seen, tends to get reduced or becomes entirely wanting in the larval stages As for the Cestoda, the digestive tract is entirely absent as the parasites absorb their nutriment directly though the soft integument of their bodies, which are immersed in the digested food or some of the vital fluids of the host The locomotor organs are also very ill-developed In the endoparasitic Trematoda these are present in the free-swimming larvæ only, cilia in the Miracidium and tail in the Cercariæ The adult fluke possesses a spiny surface which helps movement to a certain extent Apart from this, locomotion is practically non-existent in the internal parasites, and in the Cestoda even the larvæ manage to pass from host to host by merely passive methods In conformity with this the musculature is very poorly developed in the endoparasites as also the nervous system and sense organs This observation is confirmed by the fact that the larval forms like Miracidium, etc , alone possess the eye-spots In the Cestodes the nervous system is best developed in the head or scolex region, while it is practically defunct as a sensory apparatus in the hinder region Cilia are absent in all endoparasites, and this is correlated with their loss of locomotion and of respiration The excretory organs are normal.

248. Modification in Reproductory Organs.—The Reproductory Organs alone show not only any want of reduction but a high degree of development both in complexity and in the provision made for producing a large number of germ cells This is a modification directly correlated with parasitic habits The large number of germ cells is a sheer necessity to parasites which are incapable of moving about freely and infecting new hosts Indeed, but for such liberal provision the race would soon become extinct Each animal is capable of producing thousands of eggs, and at every stage in the development of the eggs an element of chance comes in The eggs and the larvae, unless they come across suitable conditions for their development, are destined to die, and only a very small proportion of the eggs can ever reach the adult stage and continue the species Most internal parasites live in specific hosts and their larvae also have to find suitable intermediate hosts in which alone they can develop properly, and this makes the chances of development all the more precarious To a certain extent this disadvantage is counteracted by the ability of certain larvae like the sporocyst and radiae of the liver-fluke and the bladder-worm of *Taenia echinococcus* to increase their numbers asexually. The large number of segments produced by a tape-worm each of which is, as far as reproduction is concerned, a distinct individual is another instance of the same phenomenon.

REVISION QUESTIONS

196 The Turbellaria combine a ciliary with a mascular method of locomotion What is the significance of this ?

197 Why do you consider *Planaria* to be more typical of the phylum than the liver-fluke or the tape-worm ?

198 What are the systems of organs met with in the Platyhelminthes, but not in the Coelenterata ?

199 Why do you describe the Platyhelminthes as triploblastic ?

200 There is no skeleton of any kind in Platyhelminthes Is there any relation between this and the parasitic nature of the Phylum ?

201 Account for the fact that cilia are entirely absent in most Trematodes and all Cestodes

202 Why is it that in the parasitic flat-worms the general tendency is towards the suppression of locomotor organs, digestive organs, and nervous system , while the reproductory organs become more advanced ?

203 Give reasons in support of the view that the Trematoda are descended from the Turbellaria

204 Explain why 'liver-rot' is prevalent in marshy districts

205 What is the relation between the great length of *Taenia solium* and the nature of its habitat ?

206 What are the common Cestode parasites of man ? How would you distinguish between them ?

CHAPTER 26

PHYLUM NEMATHELMINTHES—ASCARIS LUMBRICOIDES, THE HUMAN ROUND WORM—SOMA AND GONAD—CHARACTERS AND CLASSIFICATION OF NEMATHELMINTHES—HUMAN PARASITIC ROUND WORMS

Material for Study Specimens of male and female *Ascaris lumbricoides*, micro-slides of male or female *Trichocephalus*, male and female *Ancylostoma*, male and female *Oxyuris vermicularis*, t s male and female *Ascaris*, *Trichina* larvae in muscle, eggs of *Ascaris*, *Trichocephalus* and *Ancylostoma*, free-living and parasitic forms and rhabditis and filariform larvae of *Strongyloides stercoralis*

ASCARIS LUMBRICOIDES

249. External Features.—*Ascaris lumbricoides* is the common human round worm *A megalocephala* is a very closely allied worm found in the horse It is often passed out in the stools alive The female is larger than the male, the size of the adult female being 3 to 16 inches long and 1/4 in. in diameter.

Examine full grown male and female worms The body is cylindrical and of a light yellow colour when live. Two white streaks mark the dorsal and ventral sides respectively, while two others of a brown colour are along the lateral sides The former are the **dorsal and ventral lines** and the latter the **lateral lines.** The **mouth** is anterior and terminal, and is bounded by three lips, one median and dorsal and the others ventro-lateral The **excretory pore** is placed about 2 mm. from the anterior end ventrally A short distance from the posterior end is the **anus** marked by a transverse opening with thick lips. This opening is also the genital pore in the male The **female genital pore** is placed on the ventral side, about 1/3 of the length behind the anterior end of the body

The male is distinguished from the female by several external features. As already mentioned, it is smaller than the female Its posterior end is curved ventralwards (Fig 77, A) in the form of a hook, while in the female the lateral profile is almost straight A pair of **penial setae** or needle-like chitinoid structures project from the genital aperture of the male.

(97) Sketch the male and female worms side by side, noting particularly the sexual dimorphism.

250. Dissection of the Body Cavity.—Make out the dorsal side with reference to the lips, the curvature of the posterior end in the male and the position of the genital opening in the female. Slit open the body-wall by a dorsal incision along the whole length. Pin down the cut edges The alimentary canal and reproductive organs are seen lying in the spacious body-cavity Note the muscles of the body-wall interrupted by the dorsal, ventral and lateral lines.

Practical work

The **alimentary canal** begins with the mouth which leads into a **pharynx** with muscular walls Its lumen is triradiate in section (cf the three lips above) and is of stomodaeal origin, being lined by a layer of ectoderm which secretes a cuticle as on the surface of the body. The pharynx leads back into the **intestine,** a thin-walled and flattened tube devoid of any muscular layer in it It is continued into the **rectum** at the posterior end, and ends in the **anus.** The digested food of the host is sucked by the muscular pharynx and absorbed by the walls of the intestine There is no digestion taking place, and there are no digestive glands.

is fairly well developed. There is a ring round the pharynx from which are given off six nerves backwards and six forwards Of the former, one lies in the dorsal line and another in the ventral line. These two are connected with one another by transverse commissures. The ventral nerve swells into a ganglion just in front of the anus The remaining four are lateral, two on each side All the nerves, it will be noted, still retain their connection with the epidermis or ectoderm from which they take their origin In most animal groups, the nerves, however, come to lie definitely within the ectoderm The condition in *Ascaris* is therefore primitive The only **sense organs** are the sensory papillæ found on the lips As already mentioned, the soft protoplasmic processes of the muscle-cells may have a nervous function.

253. Origin of Soma and Gonad.—The development of *Ascaris megalocephala*, the horse round-worm, is of peculiar interest in as much as the cells that would give rise to the gonad and therefore to the gametes are differentiated at a very early stage of segmentation from those that are to give rise to the rest of the cells of the body The former are called the cells of the gonad, while the latter are the cells of the soma. The differentiation between the two makes its first appearance in *A megalocephala* when the zygote has divided into the first two blastomeres. As these commence the next mitosis a difference becomes apparent between them In one the process is perfectly normal , in the other the chromosomes are modified before the next division. Each of the two blastomeres divide , the one with the modified chromatin gives rise to two cells like itself The other divides into two also, but one of the two daughter cells undergoes a modification of its nuclear contents similar to that undergone by one of the cells of the two blastomere stage, while the other retains the characteristic nucleus of its parent-cell At each successive division of this cell, which is like the zygote in its nuclear content, one of the daughter-cells become modified as before and its daughters are also similarly modified, but the other retains the characters of the parent cell. This may go on for a number of cell-generations (it is not exactly known for how many), but it has been traced through the first four divisions resulting in 16 cells, of which one is the primordial germ cell with nuclear content similar to the zygote, while the other 15 are modified cells or cells of the soma. It is from the primordial germ cell that all the cells of the gonad are derived (cf. Sect. 162 and 168)

The fact that *Ascaris megalocephala* has only four chromosomes in each cell of its body makes the following up of the chromosomes of the nuclei in its development easier than in other animals in which the chromosome number is much larger But there is evidence derived from other animals to show that in all animals the germ substance is set apart early in development from the somatic substance. It is from the former alone that the germ cells and therefore future generations of animals of the same species can be produced, while the soma perishes every generation after it has lived for a certain time

254 Characters of Nemathelminthes.— The Nemathelminthes are a group of worms characterised by their cylindrical or thread-like shape, as distinct from the flattened bodies of the Platyhelminthes The body shows no segmentation whatever Beyond this the three classes, Nematoda, Nematomorpha and Acanthocephala which constitute the phylum have little in common

255. Classification of Nemathelminthes. — Nemathelminthes are classified into three classes —

i. Class Nematoda.—Nemathelminthes with cylindrical elongated body pointed at both ends The body-wall consists of a tough external cuticle, an ectodermal syncytium and a single layer of muscular fibres which are highly characteristic There are one or more longitudinal 'lines,' dorsal, ventral or lateral, which interrupt the musculature in one or more places The body-wall encloses a body-cavity containing a clear fluid and more or less encroached upon by the processes of the muscle cells The alimentary canal is straight and consists of pharynx, intestine and rectum The pharynx is a stomodæum The mouth is anterior and terminal and the anus ventral, placed a short distance from the posterior end Excretory canals running in the lateral lines are usually present. The nervous system consists of a pharyngeal ring and longitudinal nerves arising from it. The cords are either a single ventral cord, or two when they are ventral and dorsal, or more than two. The members of the class are dioecious and produce eggs in large numbers which are impregnated within the body of the female. The sperms are non-motile. Cilia are totally absent in the class. The majority of the forms are free-living, either in fresh or salt-water, damp earth or male is modified in the form of a pair of flaps which it uses for gripping the female in the act of copulation. The eggs are laid in the intestine and are passed out along with the fæcal matter If the ground is moist and warm the eggs hatch out in about two days into a small larva about 0 25 mm long These are called Rhabditis larvæ. The larvæ feed actively on fæcal matter and grow to double their length. They now moult their cuticle and in about ten days cease to feed, and become sluggish However, in this condition they are capable of remaining alive for several months in moist surroundings This stage and this alone is capable of infecting a new host after a second moult has taken place.

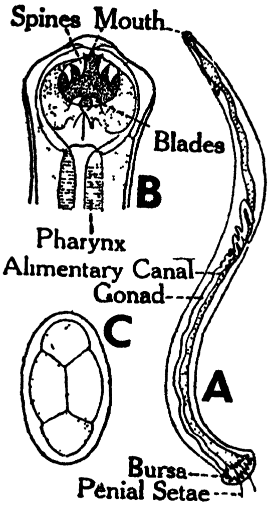

Fig 81 *Ancylostoma duodenale* **A**, male (X 8), **B**, ventral side of head showing mouth and spines, **C**, an egg (X 330)

Infection is either directly through drinking water or other articles of food contaminated with the larvaæ But more often probably it is through the skin, commonly the soft skin between the toes of people who are bare-foot. From the skin they pass into the blood-stream and reaching the lungs penetrate into the air passages of the lungs and creep up the wind pipe to the glottis and so into the œsophagus and ultimately into the duodenum In about two months the adult stage is reached and fresh eggs are laid

(102) Sketch the male and female and the eggs of Ancylostoma duodenale

259. Necator americanus.—This is the American prototype of the old world *Ancylostoma*, though it is by no means confined to America, and coexist with *Ancylostoma* in many parts of the world including India The two genera are closely related and very similar in their structure, habits, and life-history. However they differ from each other in a few respects. *Necator* is smaller than Ancylostoma and has a sharply bent head, and in place of the recurved teeth it has sharp cutting blades.

260. Ascaris.—*A. lumbricoides* is found in the human intestine and is a cosmopolitan genus, an almost identical Ascaris being found in the pig The eggs are passed out along with the fæces of the host, and the presence of the parasite can, therefore, be made out by microscopic examination of the fæces as well as by clinical symptoms

The eggs have a characteristic shape (Fig. 77, D) on account of an irregular albuminous coat, studded with warts and are about 1/16 mm. in length. They are highly resistent to extreme cold and can continue to develop in strong acids, alkalies, etc. However they cannot stand heat above 100° F. A warm (not excessively hot), moist soil seems to be the best medium for the development of the embryo, and in about three weeks of development it reaches an active stage within the egg-shell, when, if swallowed by man, it hatches in the small intestine Polluted water and food are the means of infection under normal circumstances The larvæ do not directly develop into adults, but penetrate the mucous membrane of the small intestine and entering the portal circulation, reach the liver, the heart and the lungs. From the pulmonary arterioles, they migrate into the bronchioles, bronchi, trachea and the throat, and are once again swallowed. During this circuit, which takes ten days to complete, the larvæ grow to ten times their original length Maturity is reached in the intestine in two to two and a half months

(103) *Sketch the eggs of Ascaris lumbricoides under the microscope.*

261. Oxyuris vermicularis.—This is a small nematode found in the large intestine of man and causes what is known as 'worms' in children. The mature female travels down the intestine to the anal opening to deposit the eggs Infection is direct

262. Strongyloides stercoralis.—*Strongyloides* occurs as a parasite in the intestinal lining of man, and is peculiar in that only females are met with in the adult condition. The parasites are extremely small, over 2 mm in length and are confined to the warmer parts of the world They are associated with an intermittent chronic diarrhoea. The eggs which are believed to be parthenogenetic (i e., develop without fertilisation) hatch out immediately they leave the mother's body and may escape to the outside along with the fæces as embryos. They may transform directly into larvæ capable of boring through the skin and reinfecting a fresh host, or they may develop into a sexual generation of males and females, which gives rise to fertilised ova, developing into 'rhabiditis' larvæ. The latter metamorphose into larvæ capable of boring into the skin and infecting a new host.

(104) Sketch the free-living adults, the intestinal female, the rhabditis larva and the infectious (or Filariform) larva, under the microscope.

263. Wuchereria (Filaria) bancrofti.—This is a nematode worm which is believed to be the cause of the disease known as Elephantiasis The parasite is found in the tropics and inhabits the lymphatic spaces of man The female is 10 cm. and the male 4 cm. long and very slender The newly hatched larvæ pass into the lymph system. Each is 0 3 mm. in length and is enclosed in a loosely fitting tubular membraneous sheath closed at both ends, in which it lashes about actively backwards and forwards From the lymph the young parasites pass into the blood in which they may be present in millions without affecting the host appreciably However, parasites cannot be seen in the microscope when the blood is examined during day. On the other hand, blood taken at night alone shows the parasites. This is due to the fact that during day they migrate to the deeper vessels of the body It is interesting to note that part of the life-history of the parasite is passed in a mosquito of nocturnal habits (See Sect. 330) When the larva passes into the stomach of the mosquito, the sheath is got rid of, and in a few hours time it bores its way through the alimentary canal into the muscles of the thorax Thence after growing to five times its length it makes its way to the proboscis of the mosquito

The swelling of the lower parts of the body which is characteristic of Elephantiasis is supposed to be caused by the obstruction of the lymphatics by the adult parasites or their eggs

264. Loa loa —This is called the African eye-worm, because creeping under the skin of the body generally it often shows itself up by traversing the front of the eye-ball The adult female is 45 to 60 mm and the male 25 to 30 mm The embryos, ensheathed in the softened egg-shells, which are deposited in the sub cutaneous channels excavated by the parents, reach the lymph and ultimately the blood, in which they are found in large numbers during day time, but not at night—just the opposite of what happens in *Wuchereria bancrofti.*

The intermediate host is the mango-fly. After being sucked up, they undergo some transformations in the body of the fly and ultimately pass into the proboscis, enabling the fly to transmit them into a new host by its bite.

265. Dracunculus (Filaria) medinensis.—This is the Guinea worm. It is a parasite of man and other mammals throughout the warmer parts of the world. The parasite lives in the connective tissue, and when full grown the male is 22 mm. long, while the female is 120 cm. long, but only 2 mm. wide The male dies after fertilisation, but the female with the millions of eggs it contains migrates to the skin, usually to some part of it that is liable to become wet. Here the head of the worm bores towards the surface and the epidermis forms a blister which bursts and ulcerates If the ulcer comes into contact with cold fresh-water, the worm contracts its body and discharges into the water a drop of fluid containing myriads of young larvae not more than 0 5 to 0·7 mm. in length If in three days' time they happen to be swallowed by the small fresh-water Crustacean, *Cyclops*, the larvae bore their way into the body-cavity of the host and undergo certain changes If the *Cyclops* passes into the human alimentary canal in drinking water after the larva has been five days in the Crustacean, the larva undergoes its full development and growth in the human host

266. Free-living Nematodes.—There are a very large number of non-parasitic Nematodes which live in fresh-water, moist soil, latex of plants, vinegar, flour-paste, etc Several are marine Their general organisation, particularly the thick cuticle, absence of pigment, inefficient movement, want of sense organs, simple alimentary canal, prodigality of reproduction, etc , is eminently suited for a parasitic life, and it is noteworthy that even as free-living organisms, they are almost always in hiding, so to say, shunning light and never making themselves conspicuous like their parasitic ancestors Their small size also helps them to escape easy detection They are in no way useful to man and do a lot of damage to our crops.

REVISION QUESTIONS

207 How is food taken by *Ascaris ?* Is it digested ? If not, why not ?

208 Mention an instance known to you in the Protozoa in which there is a distinction between the germinal or reproductory portion and the somatic or vegetative portion of the body

209 Account for the fact that Nematodes are devoid of pigment and efficient locomotor organs, and are covered by a fairly thick cuticle

210 What useful purpose is served by the annular ridges formed by the transverse wrinkling of the cuticle of *Ascaris?*

211 The Nematodes retain the cylindrical shape of body whatever their habitat and mode of life Account for this

212 The male and female reproductory organs of Nematoda are built on the same plan What is the probable significance of this?

CHAPTER 27

PHYLUM ANNELIDA—PHERETIMA POSTHUMA, AN INDIAN EARTHWORM —BODY LAYERS OF THE EARTHWORM, POLYP AND PLANARIA COMPARED

Material for Study Live and preserved earthworms,* micro-slides of t. s earthworm across intesinal region and of chaetae of earthworm

267. External Features.—(Fig 82) Examine a living and a spirit preserved worm Note the shape of the body and the segments of which it is made. The anterior end is slightly thicker than the posterior end, the dorsal side may be slightly darker than the ventral, the former being also marked by a conspicuous red line, a blood-vessel seen through the skin. We have thus an animal with a well developed bilateral symmetry as in the flat-worms, characteristic of free-moving animals in which the anterior end of the body is related to the direction of progression and the ventral side to the substratum

Practical work

The **mouth** is placed right at the anterior end, overhung by a small fleshy lobe, the **prostomium.** The **anus** is at the posterior end on the last segment In addition to these openings, note also the following with the help of a lens : **dorsal pores,** one for each segment placed in the mid-dorsal line intersegmentally If a freshly killed worm is gently squeezed between the fingers in two places

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* To kill and preserve earthworms, Dr Bahl recommends the following method 'Worms intended for dissection should be narcotised in weak alcohol prepared by adding small quantities of rectified spirits to the water which contains the worms Earthworms narcotised this way die in an extended condition and should further be stretched by pinning them at the anterior and posterior ends They should then be fixed in 5% formaline for a day or two and finally transferred to 90% alcohol '

A good method of stowing them away is to put as many of them as would fill a test-tube or specimen tube with a broken bottom without bending and parallel to one another. Several such tubes can be put into a large jar with sufficient alcohol to cover the specimens entirely about an inch apart, it will be seen that a fluid, the coelomic fluid, exudes through these pores. In the preserved specimen they are easily seen with the help of a lens. The first dorsal pore occurs in the intersegmental groove 12/13 (i. e., between segments 12 and 13). In mature worms there is a prominent girdle of glandular tissue covering three segments beginning with S 14, known as the **clitellum.** On the ventral side of S 14 is the single median female genital opening The **male genital openings** are a pair on the ventral side of S 18 and are marked by prominent raised paired **genital papillae.** There is in addition a pair of similar papillae on S 17 and S 19, devoid of any opening, but with a cup-like depression on their summit These are suckers by means of which the worms adhere to each other in copulation In 5/6, 6/7, 7/8 and 8/9 are four pairs of **spermathecal openings** placed ventro-laterally

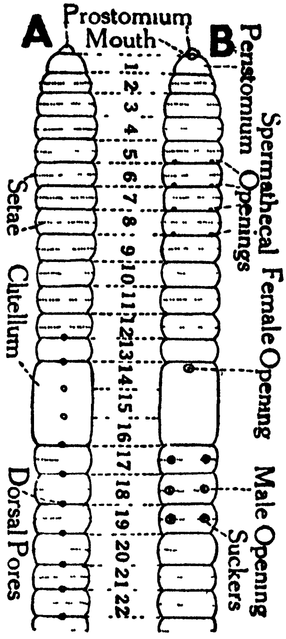

Fig 82 *Pheretima posthuma*, **A**, dorsal and **B**, ventral view of anterior end, diagrammatic, to show positions of external openings 1—22, the 22 anterior segments

If a worm is drawn between the fingers you get a sensation of roughness as it passes backwards, while, in the opposite direction it slips easily between them On close examination with a lens you will see that about the middle of each segment, except the very first and the very last, is a row of minute chitinous points, projecting from the surface of the segment slightly backwards. These points are the exposed ends of the **chaetae,** the greater part of whose length is embedded in the body-wall.

The first segment is called the buccal segment or **peristomium.** The prostomium is considered to be merely a sensitive process of the peristomium overhanging the mouth.

(*105*) *Sketch the dorsal and ventral views of the anterior end of the worm (the first 25 segments) side by side. Mark and number the segments. Locate and label all parts seen with reference to the segmentation of the body.*

Examine the slide of the chætæ under the microscope

(*106*) *Sketch the chætæ.*

268. General Dissection.—(Fig 83) Lay the preserved worm on the dissecting board dorsal side up Pin down the anterior end and then put a pin through the posterior end, slightly stretch the body so as to straighten it out thoroughly and then pin down that end also. By means of a pair of fine scissors, slit through the skin, taking very great care not to cut into the gut, lest the dissection be spoilt by the mud from the alimentary canal Pin down the cut edges right and left. As this is being done, the alimentary canal will be seen to be attached to the body-wall by a number of extremely thin **septa** on both sides, arranged in a segmental or metameric manner. The position of the septa agree with the external annulations of the body The septa run around the gut There is a considerable space between the gut and the body-wall which is segmented metamerically by the septa. The space is the **coelom** or **body-cavity.** The coelom marks a definite advance in structure over the flat-worms.

Practical work

Make out the following structures in the dissection (I) The **alimentary canal,** a straight tube as long as the body Its parts are SS 1—3, buccal cavity, S 4 pharynx, part of S 4 and SS 5—7, oesophagus (first part), S 8, gizzard, SS 9—15, oesophagus (second part), S 16 to hind end, excluding the last about 25 segments, intestine, the last about 25 segments, rectum (See Frontispiece)

The **buccal cavity** which begins at the mouth is capable of being protruded and retracted by means of strands of muscle that radiate from its walls and are directed both backwards and forwards, taking their origin form the body wall The buccal cavity is followed by the pear-shaped pharynx Its anterior end is marked by the nerve ring (See Sect 280) placed in a groove between it and the buccal wall It has thick muscular walls and well developed muscle strands radiating both forwards and backwards It occupies, however, but one segment, viz, S 4, which has been considerably enlarged for its reception, by the telescoping backwards of its hinder wall. The oesophagus begins in S 4 also and is continued back to S 15 as a narrow tube In S 8 it is modified and enlarged into a **gizzard,** a hard muscular pear-shaped organ with well developed circular muscle in its wall and lined by a horny layer secreted by its innner epithelium The food of the worm is rendered into a fine pulp by the action of the gizzard before it is passed into the intestine. The **intestine** has a thin wall and is marked by annular constrictions corresponding to the coelomic septa In the 26th segment the intestine gives rise to a pair of conical outgrowths called **intestinal cæca,** extending forwards over three or four segments Their function is unknown If the intestine is slit open and the contents carefully washed away, you can see a longitudinal ridge arising from the dorsal aspect of the gut-cavity and projecting into it from S 26 backwards This is called the **typhlosole,** whose function is said to be to increase the absorptive surface of the gut The last portion of the gut (about 25 segments long) has no typhlosole and can be distinguished as a **rectum** opening out by the **anus** on the termial segment

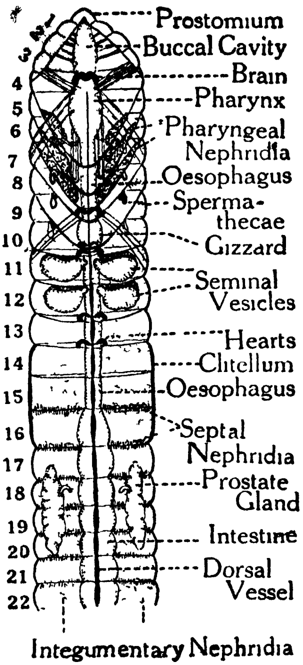

Fig 83 *Pheretima posthuma* A general dissection of the anterior end from the dorsal side, semidiagrammatic 1—22, the 22 anterior segments

(2) The **dorsal blood-vessel** is a longitudinal vessel which comes into view as soon as the body is opened In the fresh worm it can be readily seen through the skin and its contractions observed It lies immediately dorsal to the alimentary canal (3) In SS 11 and 12 are two pairs of whitish bodies lying above and on the sides of the gut These are the **seminal vesicles** whose ventral portion is hidden by the gut (4) A pair of **prostate glands** occupy the sides of the gut in SS 17 to 20 Push the prostate glands aside and note the pair of white glistening muscular **prostatic ducts** in S 18 Each duct penetrates the ventral body-wall and opens out by the male genital pore of its side

Remove the alimentary canal by cutting it at about S 35 and pulling it out forwards taking care not to detach it from the first four segments. Pin the cut end forwards gently stretched.

Note (5) the **ventral blood vessel** lying under the gut, (6) the moist. It is said that it also keeps the surface of the body disinfected against bacteria which moist soil is always teeming in. Almost all the chambers, as is seen from the section, contain the excretory tubules called nephridia. The gonads, seminal vesicles, spermathecæ, oviducts, prostate glands, etc , project into the coelom.

The coelom is lined by a coelomic epithelium or peritoneum. The portion lining the body-wall is distinguished as the parietal layer or **somatopleure** from that covering the gut or **splanchnopleure.** Each chamber of the coelom corresponds to a segment of the body and forms an entire sac in itself The walls of adjacent sacs touching each other form the **intersegmental septa.**

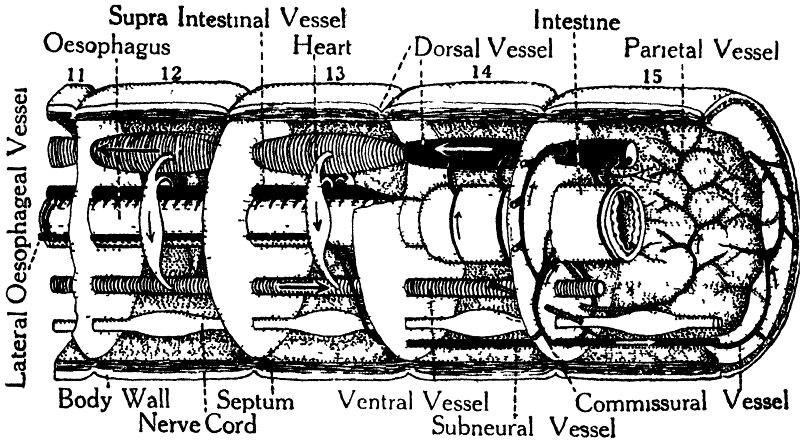

Fig 85 A stereogram of SS 12 to 15 of *Pheretima* to show the main blood-vessels and their inter-relations, distributing vessels (arteries) striped, receiving vessels (veins) dark arrows mark the direction of flow in the various vessels A little less than the left half of the body-wall is removed, left half of septum 11/12, dorso-lateral portion of peptum 13/14 on the left side and almost 3/4 of septum 15/16 are also removed (See also Frontispiece)

272. The Blood-Vascular System.—(Fig 85) The vascular system is a closed one as in the frog and contains red blood with colourless corpuscles The red colour is due to the presence of hæmoglobin dissolved in the plasma The main vessels are longitudinal and placed in the median plane These are the **dorsal** lying over the alimentary canal, the **ventral** below the gut and the **sub-neural** below the double ventral nerve cord. The blood in the dorsal vessel flows forward by the active contraction of the wall of the vessel itself. Valves are placed in this vessel intersegmentally, and the disposition of these together with the nature of the peristaltic contraction of the vessel determines the direction of the flow of blood in it. In the ventral vessel, on the other hand, the direction of flow is backwards. The ventral vessel supplies blood to the body-wall and the intestine. The sub-neural receives blood from the ventral body-wall and sends it through **commissural vessels** (segmentally arranged half-hoop-like vessels lying on the inside of the body-wall) into the dorsal vessel The dorsal vessel communicates with the ventral by means of the **lateral hearts,** pulsatile paired half-hoop-like vessels with a wide lumen occurring in SS 7, 8, 9, 12 and 13 Thus the blood received into the dorsal vessel from the intestinal region is pumped into the anterior end of the ventral vessel The dorsal vessel, then, serves as a receiving vessel in the intestinal region, whereas it becomes a distributing one in the region in front of it. The subneural vessel, in which the current of blood is backwards begins in S 14 by the union of a pair of **lateral oesophageal** vessels. Part of the blood from the latter is sent dorsalwards into a median **supraintestinal** vessel lying immediately over the oesophagus. It collects the blood from the oesophageal wall. It communicates with the ventral vessel by way of the lateral hearts in SS 12 and 13.

273. Respiration.—The body-wall, as seen above, receives an elaborate system of capillaries, separated from the outside merely by the epidermis which is extremely thin. Respiratory exchange of gases is therefore rendered easy. The surface of the skin, however, has to be kept moist always, for should the skin dry up, the animal would be asphyxiated and die.

274. Excretory System.—Excretion is carried on by means of minute excretory tubules called **nephridia.** In the general dissection (Sect. 268) we have noticed them as small tubes forming a fluffy growth on the inside of the integument (integumentary nephridia) and as small bunches attached to the septa (septal nephridia). There is yet a third kind, known as pharyngeal nephridia, from the circumstance that they open into the cavity of the pharynx. All the nephridia are bathed in the coelomic fluid.

The structure of a typical nephridium of *Pheretima* can be understood by the microscopic examination of a fresh bunch of septal nephridia in normal saline Fig 86 shows the details of structure of a single nephridium taken from such a bunch Each septal nephridium begins with (1) a small funnel or **nephrostome** followed by a short narrow tube, (2) the **body** including a short straight lobe and a long spirally twisted lobe and (3) a **terminal duct.** An intercellular (drain-pipe) tube beginning at the nephrostomal end penetrates the body of the nephridium tracing one long continuous passage and forming several parallel loops arranged in two bundles twisted upon each other. From the body the tube emerges through the terminal duct In the course of this long tube are four ciliated tracts, one in the portion following the nephrostomes, two in the body and one in the terminal duct. The excretory products are urged on from one end of the nephridium to the other by the flickering movements of the cilia Between the various loops of the intracellular tube are connective tissue and blood-capillaries, from which latter part, at least, the excretory waste is separated by the intracellular tubule itself.

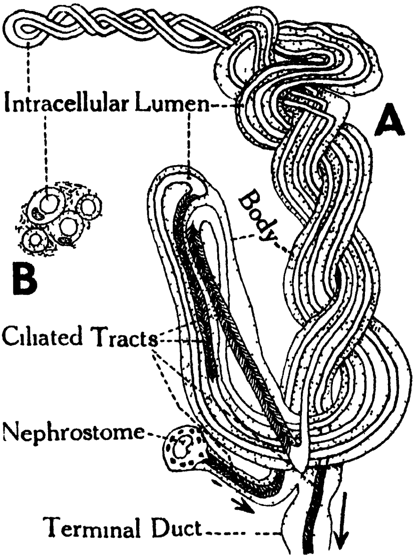

Fig 86 *Pheretima posthuma* **A**, a single septal nephridium (X 132) (altered from Bahl), **B**, a section across the nephridium showing the intracellular canals

275. Septal Nephridia.—These are found only from septum 15/16 backwards, i e., the septa perforated by the intestine. They occur in bunches of 20 to 25 nephridia attached to the anterior and posterior faces of each septum and on its right and left halves. Each complete septum thus carries four bunches. All the nephridia of a bunch open by their terminal ducts into a **septal excretory duct** which in its turn opens into one of the **supraintestinal excretory ducts.** There are two of these latter ducts placed close together between the dorsal vessel and the intestine. They open into the intestine by short narrow intersegmental ducts. Thus the excretory matter separated by the septal nephridia is discharged into the lumen of the intestine and ultimately to the outside at the anus.

276. Integumentary and Pharyngeal Nephridia.—The integumentary nephridia are the smallest of the three kinds and are found in all the segments except the first two. In structure, they are essentially like septal nephridia described above, but without a nephrostome They open to the outside, each by its own independent **nephridiopore** or external opening, directly on the surface of the skin. The large numbers of integumentary nephridia give the inside of the clitellar segments a velvetty appearance under the microscope.

The pharyngeal nephridia are confined to the fourth, fifth and sixth segments on each side of the œsophagus (See Frontispiece, 19) Each is a tuft of a large number of small nephridia joined together by their ductules to give rise to a long duct passing forwards along the side of the pharynx and opening into the buccal cavity and pharynx, the openings of the third pair being anteriormost and of the first pair posteriormost. Their position and the fact that they discharge into the buccal cavity and pharynx suggest that they are nephridia modified as digestive glands

277. Chloragogen Cells.—On the surface of the intestine and on certain blood-vessels the cœlomic epithelial cells get modified into what are known as the yellow or chloragogen cells highly charged with uric acid and glycogen. When thus highly charged they become incapable of life The dead cells pass into the cœlom where they disintegrate and, it is believed, pass into the nephrostomes of the nephridia and thus to the outside, along with the excretory products contained in them.

278. Reproduction.—(Fig 87) Earthworms are hermaphrodite, that is, both male and female organs are found in the same individual. However, cross fertilisation alone can take place. In addition to the gonads which produce the germ cells, there are several accessory organs, for the discharge of the sperms and eggs, for the reception of the sperms from another individual in the act of copulation, and for the production of a cocoon into which the egg is received and in which it is fertilised.

Male Organs. In SS 10 and 11 are two pairs of **testis sacs**

(Frontispiece, 29&33) in which the paired **testes** and **seminal funnels** are placed. Each testis sac is continued dorsally into a pair of **seminal vesicles** lying in the segment immediately behind, that is, in SS 11 and 12. They have a creamy white colour in the fresh worm. They store up the sperm mother cells (gametogonia) produced by the testes. The various stages in their spermatogenesis can be easily seen under the microscope by examining a small bit of a semina vesicle well teased in normal saline Stages in the life cycle of a Protozoan parasite, *Monocystis* (See Sect. 184), can also be seen These parasites penetrate the sperm mother cells from which they derive their nutriment by absorption. The **seminal funnels** have ciliated edges, and are therefore also called ciliated rosettes. They are placed close behind the corresponding testes and lead into the **vasa deferentia.** The two vasa deferentia of each side run a parallel course in the body-wall backwards till they open into the inner end of the prostatic duct of that side The prostatic ducts open out on the ventral side of S 18 by the male genital openings (See Sect 267)

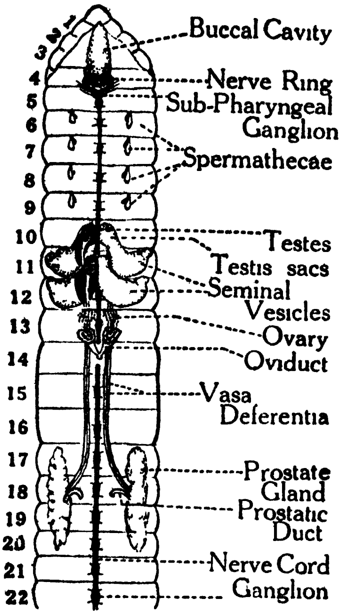

Fig 87 *Pheretima posthuma* A dissection of the anterior end to show the reproductory organs and the central nervous system The alimentary canal except the buccal cavity is removed Testis sacs are exposed on the left side to show the testes and funnels 1—22, the 22 anterior segments

Female Organs. There is but a pair of ovaries. These lie in the 13th segment, attached to the posterior face of the anterior septum, on either side of the nerve cord (See Frontispiece, 37) Each is made of a small bundle of tubes which have a beaded appearance on account of the contained ova Behind each ovary, in the same segment is a short **oviduct** with a funnel-like opening. The eggs are dehisced into the cœlom and are taken up by the funnels of the two oviducts, which open externally on the ventral side of S 14 by a common median opening.

The **spermathecæ** (Sect. 268) are also part of the female system, in as much as they receive the sperms from another individual during copulation, and store them till they are needed. The **clitellum** is a girdle-shaped gland on the outside of S 14 to 16. It is more conspicuous in the sexually mature worm than in others and in the breeding season than at other times Its outline is more clearly made out in the preserved specimen than in the fresh It secretes the substance of which the cocoon is made

279. Copulation.—The process of copulation has been studied in the European worm *Lumbricus* and in the Indian worm *Eutyphœus*. In the latter copulation takes place during the monsoon months. Early morning before sunrise, two worms from adjoining burrows become attached to each other in a head-to-tail manner by the anterior region of their bodies in such a way that the male openings of each worm are opposite the spermathecal pores of the other, with the intervening region of the two worms closely applied to each other The region round the spermathecal openings are pushed out in the form of papillæ which closely fit into the cup-shaped depression in which the male genital pores open on S 18 The penes and the penial setæ are then inserted into the spermathecal pores The spermatic fluid is exchanged mutually and is stored up in the spermathecæ The entire process takes less than an hour, after which the worms separate

In course of time the eggs mature The clitellum secretes actively and the secretion on exposure to air hardens into a horny girdle. The worm now wriggles out of the girdle which moves forward An egg is caught in it as it passes the openings of the oviduct (S 14), and a certain amount of spermatic fluid as it passes the openings of the spermathecæ Fertilisation therefore takes place inside the cocoon A certain amount of albumin is secreted by the anterior segments which is also stored in the cocoon for the food of the developing embryo When the cocoon passes the anterior end of the worm, its ends close by elasticity The fully formed cocoon is round or oval in shape and not more than 2 mm in diameter.

280. The Nervous System.—(Fig. 87) The central nervous system consists of a ventral paired **nerve cord** running the whole length of the body and placed next inside the muscles of the body-wall and a circumpharyngeal **nerve ring** at the anterior end, of which the cords form a continuation The dorsal aspect of the ring is the **brain.** The right and left moieties of the ring meet in a ventral **sub-pharyngeal ganglion.** The cords pass backwards from this, and in each segment they meet in a ganglion, so as to form a chain of ganglia The brain and ventral ganglia are nerve centres, and peripheral nerves arise from them The entire nervous system shares in the segmental plan so characteristic of the worm

There is thus in the Annelid worms a well-developed nervous system—more developed than in the Platyhelminthes In *Hydra* and the Coelenterates in general, there is only a diffuse plexus of nerve fibres and ganglion cells immediately under the epidermis In the Platyhelminthes the plexus becomes a more concentrated nerve tissue made up of a brain and a pair of lateral cords, at the same time migrating from a sub-epidermal to a sub-dermal position In the Annelids the two lateral cords are approximated and lie in a median ventral position and develop nerve centres in the form of the segmental ganglia

Earthworms are now known to possess three kinds of **sense organs.** These are (1) the **light-cells** formed in the epidermis and on some of the nerves close to their terminations in the skin They are numerous at the anterior end and occur throughout the surface, but are entirely lacking on the ventral side They consist of single cells with a hyaline lens in each and containing a plexus of nerve-fibrils coming from the nerve supplying the cell , (2) groups of special cells in the epidermis slightly elevated from the general surface form **epidermal sense organs,** tactile in function, probably also meant for the perception of vibrations, (3) similar organs are found in the buccal epithelium, and constitute the **buccal sense organs**'and are probably olfactory and gustatory in function

281. Metamerism.—The most outstanding structural characteristic of the earthworm is that its body is segmented into a large number of similar segments or **metameres.** Each metamere may be considered to be a unit made up of parts of the essential systems of organs Each externally marked segment has its coelomic chamber, nerve ganglion, excretory organs, transverse loops of blood-vessels, dorsal pore, chaetae Even the genital organs, which apparently do not share in the segmentation, show a repetition of similar parts in the testes sacs, seminal vesicles and spermathecæ Indeed there is reason to believe that the genital organs were, in the remote ancestors of the earthworm, of a metameric nature.

282. Regeneration of Lost Parts.—We have seen that animals like *Hydra* and *Planaria* possess considerable powers of regeneration. Earthworms also have this power in varying degrees. Much is not known about the extent to which *Pheretima* displays this faculty. But *Perionyx excavatus* is known to possess this power to a much higher degree than most other earthworms If the whole of its anterior region including seventeen segments is lost the posterior portion can regenerate an entire new head If more than seventeen anterior segments are lost, a head can still regrow, but the number of segments will be less than those lost. Indeed a head can regrow even if two-thirds of the worm from the anterior end is lost Anterior ends comprising 20 or more segments may regenerate a tail A piece 20 or more segments long from the middle of the body may regenerate a head and a tail. The tail end undergoes fragmentation by autotomy

283. Habits.—Earthworms are of several genera and species Several species are found in most localities, and the number of individuals in each species is very large. The worms live in the superficial soil, rarely below a depth of 18 inches In the dry weather they go deeper in search of moisture, without which they cannot live, as they respire only through the skin. In the heavy rains they come out of the soil, and crawl about on the surface of the ground in large numbers, especially where the soil is soft and alluvial. Earthworms are nocturnal creatures, coming out of their burrows at night for feeding; but they do not leave their burrows altogether, their tail ends never coming out of them In making the burrows the worms eat their way through the soil, and after digesting the organic matter, cast out the indigestible parts on the surface at the top of the burrow in the form of the well known castings. In addition to this form of feeding the worms sweep round their burrows keeping the tails in the opening, gather in all kinds of organic particles and drag them into the little chamber at the bottom of the burrow. A digestive juice is secreted over them in order to soften them and render them fit to feed upon.

284. Locomotion.—The worm moves about by the active contractions of its muscles aided by the chaetae acting as pegs and preventing sliding back. In some species, the buccal cavity is protruded and attached to any stone or other object to get a grip of the ground ; the longitudinal muscles now contract, bringing the ends of the body nearer each other The posterior end moves forward as the anterior is fixed ; besides the setae which are pointing slightly backwards while allowing movement forwards, prevent any sliding back by working against the irregularities of the ground. The circular muscles now contract, resulting in the elongation of the body and the forward disposition of the anterior end, to be followed again by the contraction of the body as above described In this manner the body is moved forward by the alternate working of the two layers of muscles. Sometimes when a worm is irritated it moves by violent irregular wriggling movements in an attempt to escape the enemy without necessarily moving forward. A worm can reverse and move backwards by changing the direction of the setae. Such movement is normal when a worm withdraws itself into its burrow

285. The Earthworm, a Promoter of Vegetation.—As the worms burrow several inches into the ground they allow water and air to percolate into the soil , besides, the roots and rootlets of plants can penetrate into these burrows with ease. By the soil being brought to the surface in the form of castings and by the continual crumbling of the deserted burrows, the earth is kept constantly moving and subjected to the beneficent action of air and sunlight The organic remains carried into the burrows are softened by the action of the digestive juice poured over them, and in course of time form a rich mould which has a high manure-value In addition to these, some hold that the small stones and gravel which pass into the body of the animals, as they eat their way through the soil, are pulverised in the gizzard into a fine powder, and that this process, long continued, converts a gravelly soil into a rich fine one, suitable for vegetation. There is, however, little direct evidence in support of this view.

Darwin has estimated the work done by earthworms with great care and patience. Part of a field was covered with broken chalk and left undisturbed for thirty years. At the end of that time he found that the chalk pieces had sunk 7 inches into the soil, being, of course, covered over by worm-castings Darwin also collected the worm castings from measured areas of varying soil conditions, and found that one square yard gave three and a half pounds of castings in a year, that is, over seven tons per acre per year.

The following passage sums up the work of the earthworms in Darwin's own words. "When we behold a wide, turf-covered expanse, we should remember that its smoothness on which so much of its beauty depends, is mainly due to all the inequalities being slowly levelled by worms It is a marvellous reflection that the whole of the superficial mould over any such expanse has passed, and will again pass, every few years, through the bodies of worms The plough is one of the most ancient and most valuable of man's inventions, but long before it existed, the land was in fact regularly ploughed, and still continues to be thus ploughed by earthworms It may be doubted whether there are any other animals which have played so important a part in the history of the world as these lowly organised creatures"

286. The Body Layers of the Earthworm.—In the transverse section of *Hydra*, we have seen that there are only two layers of cells, the ectoderm and the endoderm On the other hand, in the section of *Planaria*, representing the flat-worms (Fig 72) there is also the third germinal layer, viz., the mesoderm, including the parenchyma and the reproductory organs contained in it, placed between the superficial epidermis (ectoderm) and the epithelium of the alimentary canal (endoderm) In the earthworm, we get the ectoderm, endoderm and mesoderm, but the mesoderm is much more organised, and gives rise to the muscles of the body-wall and of the gut-wall, the coelomic epithelia, blood-vessels and reproductory organs. A glance at the transverse section of an earthworm (Fig 84) clearly shows that the mesoderm has also been split up into a somatic layer and a splanchnic layer with a definite space between the two called the coelom In the vertebrates also we find the same disposition of the germinal layers and the same modification of the mesoderm (See Fig 3 and Sects 148 and 149).

It will now be seen that the evolution of the germ-layers as illustrated by the animal types we have so far examined follows the same order as is found in their development in the frog, viz, ectoderm and endoderm differentiated first, followed by the formation of mesoderm, and ending up with the further organisation of the mesoderm into two layers separated by the coelom. Accordingly we can classify the tissue-animals or Metazoa into **diploblastic** animals, with but two layers, ectoderm and endoderm, in their body, and **triploblastic** animals, with all the three layers, including mesoderm In the latter we can further distinguish those without a coelom as **acœlomata** from those with a coelom or **cœlomata.**

What has been said above may be put in tabular form as follows .—

TABLE 8

BODY-LAYERS OF PRINCIPAL PHYLA, COMPARED

GERMINAL LAYERS	DIPLOBLASTIC	TRIPLOBLASTIC			
	COELENTERATA	ACOELOMATA FLAT-WORMS	COELOMATA ANNELIDA		VERTEBRATA
Ectoderm	Ectoderm	Epidermis	Epidermis	Body-wall	Epidermis
		Circ Musc	Circ Musc		Dermis
		Long Musc	Long Musc		Muscle
		Parenchyma	Somato-pleure		Somato-pleure
Mesoderm	Absent		*Coelom*		*Coelom*
			Splanchno-pleure	Gut-wall	Splanchno-pleure
			Long Musc		Long Musc
			Circ, Musc		Circ Musc
Endoderm	Endoderm	Enteric Epith	Enteric Epith		Enteric Epith

REVISION QUESTIONS

213 In what season can earthworms be obtained in large numbers? Why?

214 How do the worms manage to keep their body-surface moist during the hot and dry seasons?

215. What time of the day are the worms more active? Why?

216 How is the earthworm suited for its underground burrowing habits?

217 Compare the body-layers of an earthworm with those of (1) the frog, (2) *Hydra* or *Obelia* and (3) *Planaria* Arrange these animals in the order of complexity of their organisation

218 What are the sense organs of the earthworm? Devise and perform simple experiments to test its powers of vision and hearing

219 How do the excretory organs of the earthworm differ from the uriniferous tubules of the frog?

220. What are the systems of organs met with in the earthworm, but not found in the Coelenterate and Platyhelminth types studied?

221 What are the organs and body-layers of the worm that are not part of the epidermis or of the endodermis (enteric epithelium)? What is the name given to this portion which includes all the muscles and the coelomic epithelia?

222. In what essential respects does the nervous system of the earthworm differ from that of the frog?

223 To what do you assign the cylindrical shape and the absence of well-developed sense organs in the earthworm?

224 What do you understand by the term metamerism? Enumerate the organs or parts of organs of the earthworm that are disposed metamerically. Does metamerism confer any advantage on the animal?

225. Does the coelom communicate with the outside? If so by what channels?

CHAPTER 28

PHYLUM ANNELIDA (Contd)—HIRUDINARIA, THE INDIAN LEECH—USE IN MEDICINE—LAND LEECHES—CHARACTERS AND CLASSIFICATION OF ANNELIDA

Material for study A few live leeches in an aquarium, freshly killed leeches, t s middle of body of the leech

287. Occurrence and Mode of life.—Leeches are fresh-water worms, commonly found in paddy-fields, marshes, swamps, ponds, etc., all over the country, except in very high altitudes. The commonest species are *H manillensis* in the coastal lowlands and *H granulosa* further inland in slightly higher regions. They usually live in water, but occasionally migrate over land to adjoining ponds or marshes. They swim by dorso-ventral undulations of their long depressed bodies They can also progress after the manner of a looping caterpillar by attaching the anterior sucker to the sub-stratum and dragging the posterior end towards it, then attaching the posterior sucker close behind the anterior and releasing and thrusting forward the latter. They rest among weeds beneath the surface of the water, and when drought threatens hide themselves in the cool and moist depths of the bed of the pond or marsh in which they live They are abundant in buffalo-tanks and other drinking places of cattle on whose blood, as well as that of man and other mammals they feed. They also attack and suck the blood of frogs, snakes, turtles, etc. They gorge themselves with blood when a meal is to be had, which would last them from one to six months, during which period, they lie concealed among the weeds and mud. It is said that leeches can live for upwards of an year without a second meal The leech then is entirely sanguivorous, and for such a manner life its structure is eminently adapted.

288. External Features.—(Fig. 88) Examine a live leech in an aquarium. Note the manner of its swimming and the way in which the anterior and posterior suckers are used for attachment and looping movements. Note also that the the body can be extended to a very great length and contracted into an almost elliptical lump. At the anterior end is a ventral cup-shaped **cephalic sucker**, at the bottom of which the **mouth** opens. At the posterior end is another, larger, ventrally directed disc-shaped sucker, the **caudal sucker.** By means of these organs the leech can adhere firmly to the substratum or to the host The **anus** is placed dorsally between the last two annuli.

Practical work

The **genital openings** are placed on the ventral side of the anterior third of the body, the anterior one being the male, and the posterior the female, the two being separated by five annuli. Seventeen pairs of **nephridiopores** are also placed ventro-laterally. In order to ascertain their position, dry a leech in the folds of a towel, and holding it between the thumb and index finger in both hands, ventral side up, squeeze the sides gently till droplets of fluid exude at one or more spots. It will now be seen that similar droplets appear at distances of five annuli headwards and tailwards.

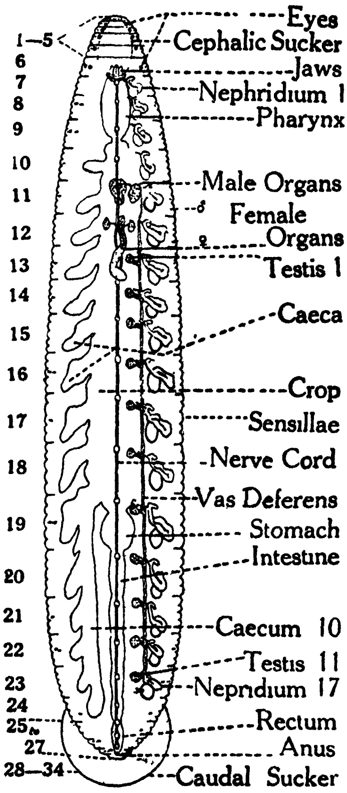

Fig 88 *Hirudinaria* A diagram of the segmentation of the leech 1—**34**, the 34 segments (including the caudal sucker) in each of which the annuli are also shown The reproductory organs are dotted, alimentary canal plain; the male and female symbols point to the grooves in which the male and female openings are placed (The segmentation adopted is after Harding and Moore, F B I. Series.)

Five pairs of **eyes** are seen on the dorsal side of the cephalic sucker as small black spots placed on an arch-like line parallel to the edge In addition to the eyes and homologous with them are the segmental **sensillæ.**

Each true segment of the body typically bears seven couples of the latter, four on the dorsal side and three on the ventral. All the seven couples are placed on a particular annulus of the segment, and are therefore indicative of the metamerism On the other hand, cutaneous **papillæ** occur on every annulus and have no metameric value.

(109) Sketch the dorsal and ventral sides of the leech side by side, marking the annuli correctly, and the external features in relation to them.

289. The Alimentary Canal.—Evert with the aid of forceps the deeper portion of the cephalic sucker which leads into the mouth, at the same time squeezing the head, so as to extrude the three **jaws,** lying at the entrance to the mouth. They radiate from the long axis of the worm, one dorsally and the others ventro-laterally Cut out one of the jaws and examine in water under the low power of the microscope, in a small watch-glass or on a pitted slide Note that the jaw is made of a mass of muscle with a semicircular edge mounted by a single row of minute, pointed, chitinous teeth Note also the numerous salivary papillæ in the form of small discs scattered over the flanks of the jaw

Practical work

(110) Sketch the jaw under the microscope

Now, squeeze out the blood through the mouth and wash well. Pin down the leech, dorsal side up, in a fairly extended condition, putting the pins through the two suckers Make a mid dorsal incision of the skin, taking care not to cut into the cavernous space inside, viz, the crop Detach carefully the body-wall from the internal organs, pinning down the detached flaps the whole length of the animal. Note the tough, dark-pigmented connective tissue filling up the interior of the worm, called **botryoidal tissue,** which has practically displaced the cœlom Remove as much of this tissue and expose the alimentary canal, from one end to the other Note the following parts Anteriormost is the **pharynx** with prominent radial muscles upon which depends the function of sucking the blood let from the wounds cut by the jaws. Next comes the large **crop** extending backwards to almost two-thirds the length of the leech and giving off paired, lateral, segmental **cæca.** The crop and cæca are easily distinguished from other tissues by their white colour and thin walls There are ten pairs of cæca increasing in size from before backwards, the last being very long and extending through several segments to almost the hind end The blood sucked up by the leech is stored in this spacious pouch and gradually passed on to the next portion, viz., the **stomach**, which is placed between the anterior ends of the two last cæca and is slightly bulbous. It is followed by a narrower tubular **intestine** the posterior end of which is the **rectum.** The **anus** as already seen opens dorsally between the two last annuli.

(111) Sketch the alimentary canal.

Practical work

290. The Salivary Glands.—Pinch off a small bit of tissue from the radial muscle of the anterior end of the pharynx. Tease it well on a slide Add a drop of water and examine under the microscope Note the large flask-shaped unicellular salivary glands seen along with the strands of muscle Their ducts open on the salivary papillæ of the jaws

The blood squeezed out from a leech is perfectly fluid and unclotted This is due to the presence of a substance called **hirudin** in the secretion of the salivary glands which mixes with the ingested blood and prevents its coagulation for weeks or even months

(112) Sketch the unicellular salivary glands.

Practical work

291 Dissection of the Nephridia, Reproductory Organs and Nerve Cord.—Remove the entire alimentary canal except the pharynx Carefully pick off the botryoidal tissue The nerve cord will now be made out along the mid-ventral line Prominent white metameric bodies on either side o it are the testes, and lateral to them are the nephridia Identify the testes and nephridia with the help of Fig 88 Clean them Note the longitudinal vas deferens. The pair of ovaries lie in the segment immediately in front of the first pair of testes Dissect out the male and female organs (Fig. 90) Make out

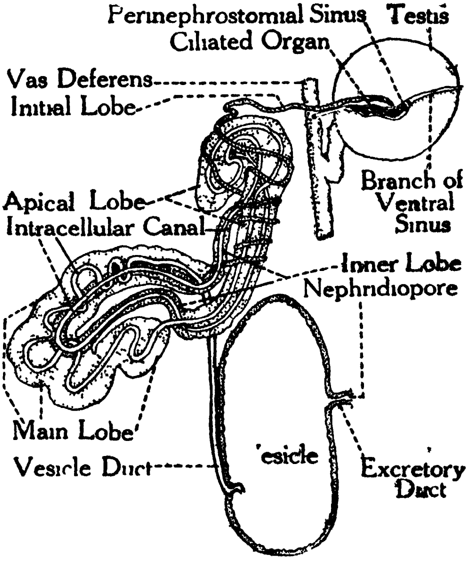

Fig 89 *Hirudinaria.* A single testicular nephridium from the left showing the main canals, together with the corresponding testis and 'ciliated organ' (Altered from Bhatia)

the 23 ganglia in the nerve cord and dissect the nerve ring which embraces the pharynx immediately behind the jaws

292. The Excretory System.— This consists of seventeen pairs of nephridia, whose external openings have already been seen. They are metamerically arranged in seventeen consecutive segments beginning with the seventh (See Table 9) The first six pairs are in the pretesticular region while the last eleven are associated with the testes of their respective segments

A typical **nephridium** (Fig 89) has the following parts the initial lobe, the apical lobe, the inner lobe, the main lobe, the vesicle duct, the vesicle and the excretory duct leading out by the nephridiopore

Remove one of the nephridia taking care not to break the initial lobe. Mount in normal saline and add a drop of glycerine Make out the parts with the aid of the figure

Inside the initial lobe is an intracellular canal The cells of the other lobes are also similarly tunnelled through by intracellular passages forming a continuous branching net-work throughout the body of the nephridium A tortuous wide channel called the central canal receives the smaller canals and is continued into the vesicle-duct Both the central canal and the vesicle-duct are also intracellular The **vesicle** is a pyriform, non-muscular bladder leading out by a short excretory duct at the nephridiopore

The initial lobe ends on the dorsal side of the corresponding testis Placed close behind the testicular end of it is an elongated cœlomic sinus, the perinephrostomial sinus, enclosing a cluster of numerous minute ciliated funnels known as the **ciliated organ.** In the embryo this ciliated 'funnel' is continuous with the initial lobe, a condition similar to what obtains in the nephridium of the earthworm (See Sect 274)

(113) Sketch the nephridium under the microscope.

293. Reproductory Organs.—(Fig 90) Like the earthworm the leech is hermaphrodite There are 11 pairs of **testes** in SS 13 to 24 arranged metamerically Each testis is placed between the nerve cord and the corresponding nephridium, and is a rounded cœlomic sac enclosing the germinal tissue. From each testis a may be seen portions of the nephridia, vas deferens, testis, perinephrostomial sinus, etc Note the absence of a perivisceral cœlom, which is much reduced and confined to the sinuses.

Examine the epidermis under the high power of the microscope and note the interspaces between the bases of the cells in which blood-capillaries run, making the skin an efficient respiratory organ

(115) Sketch the transverse section

296. The Cœlom.—The cœlom is to a great extent obliterated in the leeches, the perivisceral cavity characteristic of Annelida like the earthworm being replaced by a sponge-work, the botryoidal tissue, and certain fluid-filled spaces or sinuses such as the dorsal, ventral, testicular, ovarian, perinephrostomial, etc It is remarkable that these sinuses contain blood, coloured red by hæmoglobin The functions of the blood-system seem to have been taken over in part at least by the cœlomic sinuses However, two lateral blood vessels with contractile muscular walls are peristent and freely communicate with the cœlomic spaces, the fluid contained in them differing in no way from that which fills the sinuses.

297. Segmentation.—Careful counting will show that the body is made up of 103 annuli, from the cephalic end to the caudal sucker, equivalent to twenty-seven true somites or segments The caudal sucker is made up of seven fused segments, so that the total number of segments is thirty-four. The determination of the number of segments is based on a study of the ganglia, nephridia and the segmental sensillæ Each of the segments of the middle consists of five annuli, while those at the anterior and posterior ends have a smaller number A number of ganglia at the cephalic and caudal ends are fused, so that there are only 23 distinct ones in the adult, including 21 free ganglia and two ganglionic fusions The alimentary canal and reproductory organs also partake of the general segmentation of the body The following table presents graphically the metamerism of the leech —

TABLE 9

SEGMENTATION OF THE LEECH

REGION AND NO OF SEGMENTS	SERIAL NO OF SEGMENT	NO OF ANNULI	EYES (E), SENSILLÆ (S)	GANGLION NO	NEPHRIDIUM & NEPHRIDIOPORE NO	GONAD-OVARY(OV), TESTIS (T)	GENITAL OPENING	ALIMENTARY CANAL	
								PARTS	CÆCA NO
HEAD (6)	1	1	S	1—6 (fused)				CEPHALIC SUCKER	
	2	1	E						
	3	1	E						
	4	2	E						
	5	2	E						
	6	3	E					JAWS MOUTH	
PRE-CLITEL-LAR (3)	7	3	S	7	1			PHARYNX	
	8	4	S	8	2				
	9	5	S	9	3				
CLITEL-LAR (4)	10	5	S	10	4			CROP	1
	11	5	S	11	5		male		2
	12	5	S	12	6	OV	femle		3
	13	5	S	13	7	T_1			4
POSTCLITELLAR (11)	14	5	S	14	8	T_2			5
	15	5	S	15	9	T_3			6
	16	5	S	16	10	T_4			7
	17	5	S	17	11	T_5			8
	18	5	S	18	12	T_6			9
	19	5	S	19	13	T_7		STOMACH	10/1
	20	5	S	20	14	T_8		INTESTINE	10/2
	21	5	S	21	15	T_9			10/3
	22	5	S	22	16	T_{10}			10/4
	23	5	S	23	17	T_{11}			10/5
	24	4	S	24					10/6
ANAL (3)	25	3	S	25				RECTUM	
	26	2	S	26					
	27	2	S	27				ANUS	
CAUDAL SUCKER (7 FUSED)	28	Seven (fused)	S	28—34 (fused)					
	29		S						
	30		S						
	31		S						
	32		S						
	33		S						
	34		S						
TOTALS	34	103+7 = 110	34	6+21+7=34	17	12			15

298. Reproduction.—True copulation takes place in the leeches, often reciprocally as in earthworms. The penis of one leech is introduced into the vagina of the other and the spermatozoa are deposited in its upper part (There are no spermatophores as in the allied genus *Hirudo.*) The fertilised ova are laid in a quantity of albuminous jelly in an ellipsoidal cocoon composed of a firm horny secretion of the clitellar glands embracing SS 10—13 The cocoons are deposited in moist earth beside the water The embryos feed upon the albuminous contents of the cocoon and emerge as fully developed little leeches. Three to fourteen young emerge from a single cocoon.

299. Use in Medicine.—Leeches were once extensively used for extracting blood and relieving congestion With the advance of modern methods of surgery their use has practically disappeared from European medical practice. However, they are still largely used by votaries of Indian systems of medicine The most favoured species for blood-letting is *H. granulosa*, followed closely by *H manillensis.* Leeches are collected in large numbers for the purpose and are also cultured, and a considerable trade in leeches exists even at the present day. Cultured leeches are preferred for blood-letting The medicinal leech of Europe is *Hirudo medicinalis*

Leeches can be kept alive and sound for a long period in a jar of cold water with a little mud at the bottom and covered with a piece of muslin, the water being changed every day or two Often there is trouble in getting leeches to fix The part to which they are to be applied should be cleansed with a piece of rag soaked in cold water, or the part may be rubbed with a little sugar and water or with milk or the part may be slightly scratched with a sharp needle till blood comes If these devices fail the recalcitrant leech is often dried in a dry towel or immersed in warm water for a moment to induce it to bite. Leeches usually fall off when full, but if they do not, they should not be violently pulled out, as some teeth may in that case be left behind in the wound. A pinch of salt sprinkled over the part would make them fall off If desired the same leech can be used again. For this spray it over with a little salt so as to make it disgorge the blood. Then return to water till it revives thoroughly and is ready once again to stick,

300. Land Leeches.—Closely related to the aquatic leeches are the land leeches of the genus *Hæmadipsa*, which have adapted themselves to a purely terrestial life, though they can live only in the humid, cool interiors of tropical forests, where they are seen in teeming numbers especially during the rains In the dry season they disappear except in places with sufficient humidity. They live on the ground and on trees attached by the posterior sucker, always in readiness to pounce upon the unwary beast or man, whom they attack in large numbers, crawling up all over the body or under the clothes and inside boots, often unnoticed till they have actually gorged themselves They leave wounds which take long to heal

In other ways also land leeches affect human welfare Moore writes "There are districts so dominated by them as to be nearly uninhabitable by man They have a deleterious effect upon agriculture and stock-raising through attacks on domestic animals As they repeatedly bite in the same place the continued irritation results in persistent open sores . Attacks on the eyes sometimes cause temporary or even permanent blindness They are reputed to be the vectors of the flagellate *Herpetomonas* causing gangrenous ulcer and of the germ of tetanus "

301. Characters of Annelida.—The Annelida are bilaterally symmetrical triploblastic animals with a well developed coelom They possess a segmented body, each segment of which is essentially like any other This segmentation is primarily one of the coelom, which retains the segmented condition throughout life, while in animals like the Vertebrata, it disappears early in development The excretory organs are nephridia which by origin and structure differ from the uriniferous tubules of the Vertebrates Annelida have a well developed blood-system, but no heart Their nervous system consists of a cerebral ganglion, oesophageal connectives and a double ventral nerve cord They include the marine worms, the earthworms, (Polychæta), the leeches and a few other less familiar forms

302. Classification of Annelida.—Annelida are classified into 3 classes .

i. Class Archiannelida. Annelida with a narrow elongated body, faint external segmentation, but well developed internal segmentation, without parapodia and chætæ, the nervous system still in continuity with the ectoderm and without ganglia, sexes united in some and separate in others A primitive group, all forms marine. Example ·—*Polygordius.*

ii. Class Chætopoda. Annelida with distinct metameres chitinous chætæ set in chæta-sacs and a metameric coelom They include two sub-classes .

I. Sub-class Polychæta are Chætopoda with distinct sexes, ovaries and testes simple and metamerically disposed, parapodia well developed and mostly bearing many chætæ, a distinct head with eyes and tentacles, and often cirri and branchiae present on the body-segments There is no clitellum There is a free-swimming larva Almost all forms are marine Example —*Nereis*

2 Sub-class Oligochæta are hermaphrodite Chaetopoda, with a well developed and complicate reproductory system, with not more than two pairs of testes and ovaries , parapodia, cirri and tentacles as well as eyes absent, chaetae are few and there is no distinct head A clitellum is usually well developed. The eggs are laid in cocoons and the embryo develops directly into the adult Mostly terrestrial, but a few are fresh-water Examples —*Megascolex, Lampito, Perionyx, Pheretima,* terrestrial forms , *Chætobranchus,* a fresh-water form

iii. Class Hirudinea. Hermaphrodite Annelida with a definite number of segments, viz , 34, each segment marked externally by secondary annuli The anterior end of the body is modified into a sucker inside which the mouth opens and several of the posteriormost segments also form a large powerful posterior sucker. The coelom is always more or less obliterated by connective tissue. A penis and vagina are characteristic, development direct Free-swimming or ectoparasitic forms, terrestrial, fresh water or marine Examples —*Hirudinaria,* the common leech, fresh-water , *Hæmadipsa,* the terrestrial leech *Ozobranchus,* a gilled leech, ectoparasitic on tortoise *Branchellion,* a gilled marine leech , *Pontobdella,* parasitic 'on sharks and rays, marine.

REVISION QUESTIONS

226 Compare the earthworm and the leech, and point out the similarities in structure and function between the two

227, Mention the adaptations of a leech for a blood-diet.

228 How does the nephridium of the leech differ from that of the earthworm? Which is the more advanced type of nephridium?

229 Is the absence of a perivisceral cœlom of any advantage to the leech? If so, what?

230 What is the use of the leech in the practice of medicine? What are the advantages and disadvantages of its use?

231 Do you consider the leech as a free-swimming or a parasitic worm?

232 What are the respective functions of the botryoidal tissue, the thick longitudinal muscles of the body-wall, the dorso-ventral muscles, and the radial muscles of the pharynx?

233 Describe the structure and use of the salivary glands

234 Why does a leech-bite continue to bleed for a longer time than an ordinary wound?

235 What are the organs that are segmentally disposed in a leech? Does the alimentary canal share in the segmentation?

236 How do leeches affect human welfare?

CHAPTER 29

PHYLUM ARTHROPODA, CLASS INSECTA—PERIPLANETA AMERICANA, THE COMMON COCKROACH—LIFE HISTORY AND STRUCTURE OF MOUTH PARTS OF A BUTTERFLY—THE SILK-WORM—SILK

Material for Study Live and killed cockroaches, a few caterpillars butterflies and moths

The butterfly usually lays her eggs on the underside of the leaves of the plant on which the caterpillars feed Look for the eggs, watch them daily till they hatch into minute caterpillars, and thereafter make dated life-size drawings at regular intervals of, say, one or two days Similarly make drawings of the pupal stage (chrysalis) and of the imago (adult) when it emerges

The caterpillars can often be reared in a little box with wire gauze at both ends and a glass lid The caterpillars of any age can be transferred into such a box along with the leaves on which they feed The box should be cleaned, aired and replenished with fresh leaves daily and kept in a cool place to prevent the leaves drying up too soon

PERIPLANETA AMERICANA, THE COCKROACH

303. External Features.—Notice the division of the body into three parts, head, thorax and abdomen

(a) Head. Make out the following **antennæ** or feelers, a pair of very long jointed filaments, **compound eyes,** a pair of dark areas on the sides; **epicranium,** the part behind and between the eyes, **clypeus** in front of the epicranium, **genæ,** paired, below the eyes on the sides (All these parts are covered by

Practical work

strong plates of chitin), **fenestra,** a white spot internal to the base of each antenna, **labrum,** a broad plate hanging down from the clypeus, **oral appendages,** behind the labrum (Sect. 304) Connecting the head to the thorax is a short, small **neck.**

(b) Thorax. Note the three segments of the thorax, viz, the **prothorax,** the **mesothorax,** and the **metathorax ;** the three pairs of **legs** and the two pairs of **wings.** The prothorax is devoid of wings and is covered by a large shield-shaped **tergum** (dorsal plate). The terga of the remaining two thoracic segments are covered by the wings. Each segment has a ventral plate or **sternum** to which the legs are attached. Between the segments the skin is soft

(c) Abdomen. Note the terga and sterna of the abdominal segments, the posterior margins of each overlapping the anterior margin of the one behind Note the soft skin between the segments by stretching the abdomen gently. Notice also the soft skin between the terga and sterna on each side of the abdomen There are ten segments in the abdomen. SS 8 and 9 are reduced and hidden by S 7. S 10 is seen at the hind end, and is produced backwards as a flexible plate deeply notched in the middle line. Below this is the anus, the skin on either side of the opening being strengthened by a chitinous plate called **podical plate.** On the side of the podical plates and arising from S 10 is a pair of **anal cerci.** In the male, the 9th sternum bears a pair of slender **styles.** In the female, the 7th sternum is very much broader and modified into a keel-shaped structure. The abdomen of the female is also broader than that of the male. Examine your specimen and determine its sex Below the anus is the **genital opening** surrounded by a complicate series of plates used in copulation, called **gonapopyses.**

(d) Appendages. These are the antennæ, the oral appendages, the thoracic appendages including the legs and wings and the anal cerci.

(116) *Sketch the dorsal and ventral views of a cockroach.*

(117) *Sketch the posterior end of the abdomen of the male and female from the ventral view*

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[*] Chitin is the substance of which the hard external skeleton of insects and other Arthropods is made It is secreted all over the body by the epidermis in the form of a viscous fluid, which hardens on exposure to the atmosphere In caterpillars and spiders, it is also produced in special glands and drawn out into fine threads which on exposure harden into the silk-threads and cobweb so characteristic of these animals

Practical work

304. Oral appendages or Mouth Parts.—(Fig. 92) Examine the 'chin' of the insect and note a flat plate of chitin forming the lower (posterior) boundary of the mouth. Pull this out and place it on a glass-slide. This is called the labium (lower lip) Now pull out the other appendages of the mouth in order from behind ending up with the labrum. Arrange the appendages in the order in which they are placed in the mouth. Examine with a lens, and make out the following from in front backwards (1) **labrum** (upper lip), a median plate in front of the mouth , (2) **mandibles,** a pair of hard chitinous 'jaws' one on each side of the mouth, with a dark, serrated cutting edge ; (3) **hypopharynx,** a median tongue-like process (also called the **lingua** or tongue), (4) **1st maxillæ,** a pair, each with a basal portion of two joints called **cardo** and **stipes,** a five-jointed outer lobe or **palp** and an unjointed inner lobe consisting of two blades, the inner being the **lacinia** and the outer the **galea** and (5) **2nd maxillæ (labium)** which is formed by the fusion of the right and left **cardo** and **stipes** of these appendages into a plate The basal and larger part of this plate is called the **sub-mentum** and the distal part the **mentum.** The mentum bears paired **galea, lacinia** and **palps.** This appendage is thus seen to be very like the 1st maxilla, except that the right and left halves are fused proximally

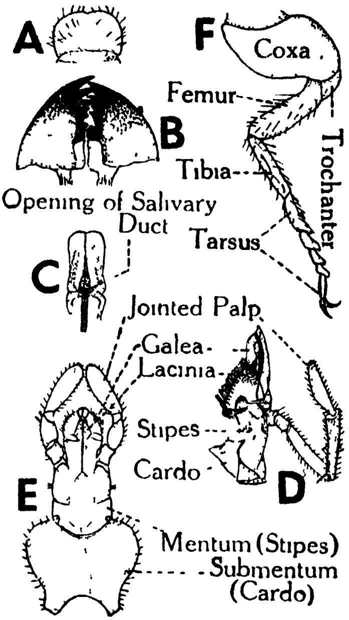

Fig 92 *Periplaneta Americana* The labrum, isolated oral appendages and a leg **A**, labrum , **B**, mandibles , **C**, tongue , **D**, the left first maxilla , **E**, second maxilla or labium , **F**, a walking leg, on a smaller scale than others

Note the hair-like processes arising from the surface of the labrum, 1st maxillæ and 2nd maxillæ. These are termed **setæ.** The lacinia of the 1st maxilla bears a row of large strong setæ on its inner side forming a brush-like organ. Setæ are found in other parts of the body as well, e g., the legs. They are to be distinguished from the chætæ of Annelida which are minute solid chitinous rods secreted by and lodged within chæta-sacs into which they can be retracted, whereas the setæ of Arthropoda are merely chitinous coverings of small papillæ of the skin arising from the surface of the body and moved by small muscles inserted on their inside.

305. Thoracic Appendages.—These are the legs and wings Each leg (Fig 92, F) consists of the following segments or podomeres (1) **coxa,** proximal, thick and broad, (2) **trochanter**, small and triangular, (3) **femur,** longest, with a row of large setæ along its hinder margin, (4) **tibia,** bearing very large setæ on both edges, and (5) **tarsus,** consisting of six short segments carrying adhesive cushions ventrally The terminal segment of the tarsus is the **pulvillus,** and bears a pair of claws

Of the two pairs of wings, the anterior or mesothoracic ones are harder and darker than the other They cover the metathoracic or flight-wings when at rest, and are distinguished as the **elytra.** The flight-wings are more membranous and folded up fan-wise when not in use Both pairs are supported by nervures or veins which form a net-work.

(118) Sketch the oral appendages and a leg.

306. Spiracles.—These are the openings of the respiratory tubes or trachea

Hold the anterior and posterior ends of the abdomen in the two hands and bend it in the horizontal plane so as to stretch the soft skin of one side The spiracles become visible as slightly dark areas against the white of the skin They are placed intersegmentally The first pair is between the pro- and meso-thorax and thereafter there is a pair in each intersegmental region There are altogether ten pairs of them, each a small slit Examine the spiracles with a strong lens There are a number of small bristles around the opening What is the purpose served by these bristles?

307. Dissection of Alimentary Canal.—Pin down the cockroach on a dissecting board, dorsal side up, by means of the legs, head and end of abdomen. Cut away the wings. Make a longitudinal cut of the terga parallel to the margin of the body of the abdomen on both sides. Remove the terga of the

Practical work

abdomen and thorax without injuring the skin below, one by one, from behind forwards.

Note the **heart** seen as a longitudinal segmented tube lying in the mid-dorsal line and the white **fat-bodies** in the body-cavity. Pick out the fat-bodies carefully.

The alimentary canal (Fig. 93, A) now comes into view It is a coiled tube with distinct parts. Straighten out its length and display it on the dissecting board on one side of the animal. Note the following parts from the anterior end backwards (1) **œsophagus**, emerging from the head and soon dilating into (2) the **crop**, a thin-walled and spacious chamber, very wide behind, often with masses of food stored inside, (3) the **gizzard**, immediately behind, bearing internally six hard chitinous teeth and behind them fine hairs which act as a strainer, (4) the **hepatic cæca**, eight hollow, finger-shaped glandular outgrowths from the anterior end of (5) the **mid-gut** or enteron, the digestive and absorptive part of the alimentary canal; the posterior end of this is marked by a number of fine yellow tubes opening into it called (6) the **Malpighian tubules**, which are the excretory organs, next come (7) a short **ileum**, (8) a wide long **colon** and (9) a short **rectum** opening out by the **anus**.

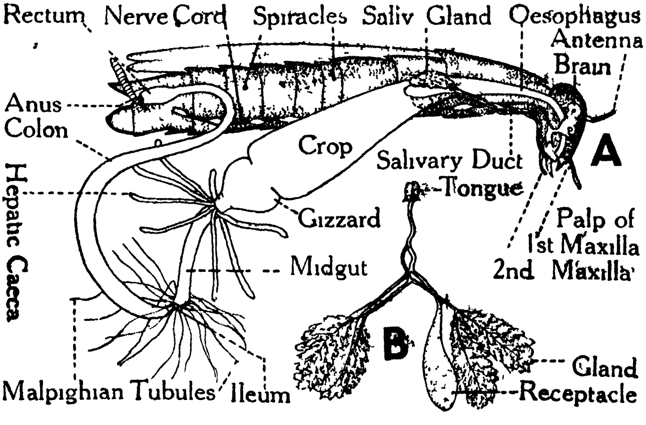

Fig 93 A, dissection from the right side with the alimentary canal partially unravelled and pulled out from the body cavity The reproductory organs are not shown. B, the salivary apparatus.

Note that the **buccal cavity** is hidden inside the head and is not seen in the dissection. The mid-gut alone serves for digestion and absorption, and is lined by endoderm cells The portions in front, up to and including the gizzard, are lined by ectoderm and cuticle and form a stomodæum. Similarly the part behind the Malpighian tubules is a proctodæum, also lined by ectoderm.

The gizzard is a small grinding mill in which the food is pulverised. Only finely broken particles are allowed to pass into the mid-gut on account of the presence of the strainer

308. Digestive Glands.—The **hepatic cæca** secrete a digestive juice which is passed into the mid-gut Note also the pair of **salivary glands** (Fig 93, B) lying attached to the anterior end of the crop at its sides. These can be seen as white lobulated structures Carefully detach one of the two glands Note the fine white glistening threads (tracheæ) by means of which attachment is effected Each gland has two main lobes and between them is a **receptacle** or thin-walled hollow bag Ducts lead from the glands and receptacles, and unite together below the gut in the neck region and forms a **common duct.** This duct opens into the buccal cavity on the lingua or tongue (hypopharynx). The secretion helps to soften the food inside the crop. It has a characteristic smell associated with the cockroach.

(119) Sketch the alimentary canal with the digestive glands

309. Respiratory System.—Remove the alimentary canal and pick out any fat-body that may remain. Note the large tracheal tubes arranged symmetrically on on a ladder-like pattern with paired longitudinal trunks and transverse commissural tubes. The spiracles open into the two lateral trunks.* Under water, the tubes are white and glistening. Why?

Practical work

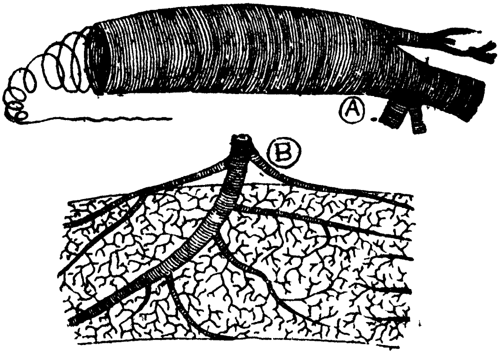

Fig 94. *Periplaneta* **A**, a trachea from the thorax, with branches, at one end the spiral thread has come loose, **B**, a portion of the midgut showing the nature of branching and anastomosis of the smaller tracheal tubes. (X about 8)

Cut out a length from one of the larger trunks from the thorax and examine under the microscope (Fig 94, A). Note the spiral structure. This is due to the fact that the soft walls of the tubes are strengthened by a spirally wound, elastic thread of chitin How, do you think, is the spiral formed?

Cut out a length of the ileum, slit it open lengthwise, wash in running water to remove food substances, if any, and examine under the low power of the microscope (Fig. 94, B) Note the trachea, their mode of branching, and how the smaller branches anastomose in several places

(120) Sketch the tracheal tubes and their branching and anastomosis

Respiration is effected in the insects in a very peculiar manner There are neither gills nor lungs. The air is taken through the spiracles and passed into the tracheal tubes These divide and redivide into fine branches, like the ones seen, all over the body Air is thus taken through the tubes directly to the various parts of the body The tracheæ penetrate the legs, the antennæ, the wings, indeed every part of the body Exchange of gases takes place between the tissues and the air in the tracheal tubes.

The air is kept in continual circulation by the alternate arching and flattening of the abdomen, drawing in and letting out air respectively through the spiracles.

The blood does not take part in the respiration--it is in the insect not a carrier of oxygen or carbon-dioxide The respiration may be said to be direct, and therefore so much more efficient than in other animals. Remembering that the insects are usually flying animals, what is the advantage of this type of respiratory organs?

310. Vascular System.—The blood is colourless Why? The gut, fat-bodies and other internal viscera float in the blood There are no regular vessels except the **heart,** which lies in the mid dorsal line under the skin (Sect 307). It is tubular and metamerically segmented, the segments being separated by valves which allow the flow of blood only forwards It is closed behind and open in front. It is enclosed in a **pericardium** which contains blood The blood from the pericardium enters the heart through paired **ostia** or valvular apertures The contraction and expansion of the heart, brought about by the **alary muscles** attached to it laterally in a segmental manner, cause both the forward flow of blood in the heart and the suction of blood into the heart from the pericardium through the ostia. From the heart the blood passes into the body-cavity from where it is returned to the pericardium and the heart.

311. Excretory Organs.—These are the Malpighian tubules, a large number of extremely fine, blindly ending filamentous tubes opening into the anterior end of the proctodæum. The tubes float in the blood contained in the body-cavity, from which they collect nitrogenous waste matter (uric acid) and pass it on to the gut, to be expelled along with the alimentary waste.

It will be remembered that in the earthworm, *Pheretima*, the septal nephridia discharge into the intestine. The ureter of the frog and most other Vertebrates also open into the hind end of the alimentary canal

312. Male Reproductory System.—(Fig 95, A) Open a freshly killed male cockroach, carefully remove the alimentary canal and the floating fat-bodies The genital organs lie at the posterior end of the body-cavity. The **testes** are a pair of lobed structures, well developed in the young males only In the older ones they are atrophied. When present they are difficult to distinguish from the fat-bodies. From each testis a **vas deferens** passes backwards and can be seen entering the paired **seminal vesicles,** the two halves of which are approximated and together form a large round bunch of finger-shaped diverticula (They are also called the mushroom-shaped glands, but are neither mushroom-like nor glandular) The sperms from the testis are passed into them, while the animal is still young. Note the large **ejaculatory duct** arising from the posterior side of the seminal vesicles Trace them on to the **male genital opening** placed between the 9th and 10th abdominal sterna. Make out also the large leaf-shaped **conglobate gland,** lying ventral to the ejaculatory duct and opening along with it The **gonapophyses** are a series of chitinous hooks and plates around the the genital opening, and aid in copulation.

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313. Female Reproductory System.—(Fig. 95, B) Similarly open a female cockroach In much the same position as the vesicula seminalis of the male lies the pair of **ovaries.** They are easily made out, as each is in the form of a bunch of bananas. Each bunch consists of eight tubes. Each tube can be seen to be beaded in appearance, with the largest and ripest ovum at the posterior end forming an oval bulging, while the younger ones lie

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anteriorly in the ovarian tube as smaller bulgings. From each ovary arises a short wide **oviduct,** and the two oviducts unite in a median **vagina,** which opens by the **female opening,** on the 8th abdominal sternum into a wide sac or **genital pouch.** The latter opens to the outside on the ventral side of the 7th abdominal segment, which is well developed and modified into the keel-shaped floor of the genital pouch The external opening is longitudinal and slit-like. Inside the genital pouch may be seen three pairs of **gonapophyses,** strongly chitinised spines which aid in depositing the eggs inside the pouch.

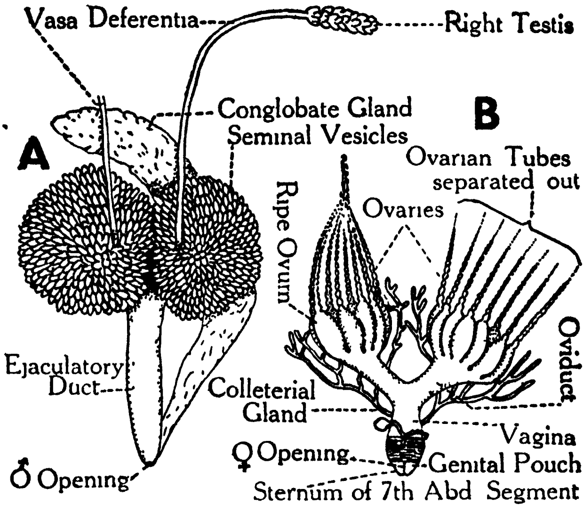

Fig 95 *Periplaneta* **A**, male and **B**, female reproductory systems, dissected out, as seen from the dorsal side

A pair of much-branched tubular **colleterial glands** and a pair of **spermathecæ** open on the roof of the genital pouch

(121) Sketch the male and female reproductory systems

314. Oviposition—The Young Cockroach.—The sperms from the seminal vesicles are passed into the genital pouch of the female during copulation and the spermatic fluid is sucked up by and stored in the spermathecae As the eggs pass into the genital pouch, they are fertilised by the sperms, the opening of the spermathecae being conveniently placed for this purpose The gonapophyses arrange the eggs, in two rows of eight each, inside the genital pouch. The secretion of the colleterial glands is poured into the pouch and hardens into a capsule around the eggs The egg-case is deposited by the female in any convenient, dark, sheltered spot. Development takes place inside the cocoon and the young cockroaches escape by breaking the egg-case open

When hatched out the young ones are tiny, whitish in colour and resembling the adults in general shape and structure, but devoid of wings Their skin is soft and glandular and secretes a viscid fluid which soon hardens into dark chitin The young ones feed and grow, and soon their cuticle becomes too small and tight and the tiny cockroach moults or sheds the cuticle in order to allow of a general expansion on the whole body, or increase in dimensions The soft glandular skin again secretes a new chitinous coat which in its turn has to be given up for a third and larger one. About seven such moults take place before full growth In a collection of cockroaches for the class, you often meet with wingless ones These are about to undergo the last moult In place of wings they have flat expansions of the hinder border of the meso- and metathoracic terga, inside which the wings, soft, crumpled and folded plates, are hidden. With the last ecdysis they are liberated, expand and become chitinised into the structures characteristic of the adult.

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315. Dissection of the Nervous System.— (Fig 96) Clean the body cavity of all the fat-bodies and the reproductory organs as well as the tracheal tubes. The **nerve cord** is now seen lying mid ventrally along the whole length of the body Clean the cord, carefully pulling away the small tracheal tubules still attached to it Note that there are two cords lying side by side Make out the three large **thoracic ganglia** and the six smaller **abdominal ganglia.** Which of the latter is the largest and why? From the various ganglia peripheral nerves arise and pass into the appendages and the body-wall.

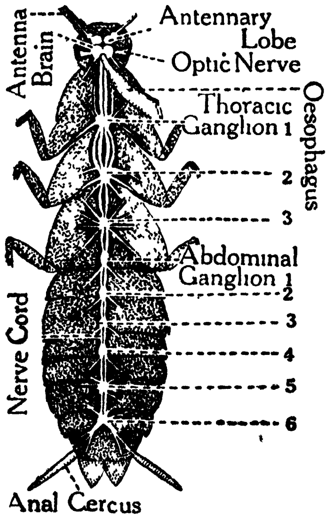

Fig 96 *Periplaneta* The central nervous system dissected from the dorsal side.

Pin down the head with the anterior surface turned upwards by means of a pin through the upper part of the epicranium, and another through the labium between the mandibles. Cut off the clypeus and as much of the epicranium as possible and expose the **brain**, the **circumoesophageal connectives** and the **sub-oesophageal ganglion.** The three together make up a thick ring through which the oesophagus passes Note the **optic nerves** arising from the dorso-lateral aspects of the brain, the large **antennary lobes** in front of the brain, and the **antennary nerves** arising from them. Make out the sub-oesophageal ganglion, and the pair of connectives between it and the first thoracic ganglion.

The nervous system of the cockroach, it will be noted, follows essentially the same plan as in the earthworm, with an anterior circumoesophageal ring and a ventral chain of segmental ganglia, connected together by a double nerve cord. However, the number of abdominal ganglia has undergone a reduction, the last or 6th abdominal representing several ganglia fused together

The brain supplies nerves to the **sense organs,** viz, the eyes and the antennae; the sub-oesophageal ganglion to the mandibles, the 1st maxillae and the 2nd maxillae, and the ventral chain to the respective segments and their appendages.

(122). Sketch the nervous system in an outline of the body with the segments numbered and the various ganglia in their respective segments.

METAMORPHOSIS OF A BUTTERFLY

316. Larva.—(Fig. 97,A) Examine a fairly full grown caterpillar. Note the elongated vermiform body divided into metameres or segments. Make out the fourteen segments of which the first is the **head,** the next three the **thorax** and the last ten the **abdomen.** The head which has a harder exoskeleton than the rest of the body does not possess the long antennæ or the large compound eyes of the adult insect, but very short inconspicuous **antennæ** and a group of **ocelli** or simple eyes. As for the mouth-parts, there are a well developed pair of **mandibles** to cut the leaves with, a pair of **first maxillæ** and a pair of **second maxillæ** fused to form a labium. In front of the second maxillæ is a small process bearing the aperture of the duct of the silk-gland (See note to Sect. 303).

The three segments behind the head correspond to the thorax, and bear on their ventral sides paired **legs,** three jointed and clawed at the ends. SS 7, 8, 9 and 10 (i. e., 3rd, 4th, 5th and 6th abdominals) bear each a pair of blunt processes ventrally, the **pro-legs,** each one terminating in a cushion. These are not jointed and are therefore not homologous with the true thoracic legs. The last segment also bears a pair of pro-legs called **claspers.** **Spiracles** open on either side of the body on SS 2 and 5 to 12 (incl.)

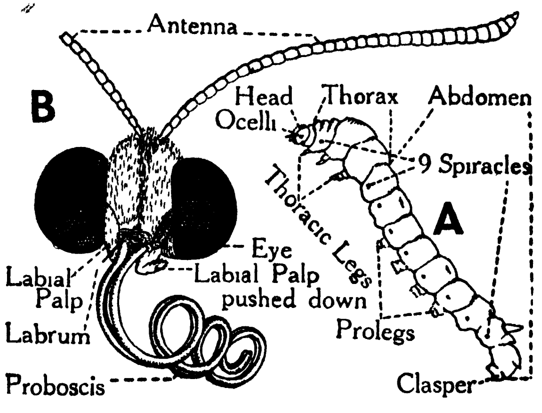

Fig. 97 **A,** Caterpillar of the Silk-Moth, **B,** Front view of the head of a butterfly, the proboscis pulled out and split into the two halves near the proximal end

The larval stage, beginning at the time of hatching is one in which the organism feeds voraciously and therefore grows rapidly. The cuticular investment which is non-living, being only a secretion of the epidermis, does not grow correspondingly, and as in the young cockroach, has to be cast away from time to time to allow of growth After each moult or ecdysis a new cuticle is secreted, at first as a viscid covering of the body, soon hardening into the tough coat. The caterpillar moults five times before reaching full size, each moult being preceded by a short period of inactivity. In moulting, the cuticle of the head is cast off entire, and the skin of the body bursts longitudinally along the back of SS 2, 3 and 4, the larva slowly crawling forwards, often making a meal of the cast skin. Each stage between moults is called an **instar.**

(123) Sketch the larva.

317. The Pupa or Chrysalis.—When full grown, the caterpillar stops feeding and wanders restlessly about till a suitable spot where to pupate is discovered. It then spins a pad of silk, which it grasps with its claspers. After a time, the skin splits and reveals within the immature pupa with rudiments of wings, legs, antennæ and compound eyes. The cuticle is cast off and a new one is secreted all over the body which has by now considerably shrunk and changed in shape Hereafter no external change takes place and to all appearances, the organism is absolutely quiescent. As a matter of fact, intense activity takes place within Breathing is carried on all through the chrysalis stage by a special spiracle The organs and tissues of the caterpillar break down and from their material are built up the organs of the adult. This rebuilding, however, had already begun towards the end of the larval stage, and is by no means so sudden as the sudden external changes marking the beginning of the chrysalis stage might lead us to think

(124) Sketch the pupa.

318. The Imago or Adult.—When these internal changes are complete, the pupal cuticle splits along the dorsal side, and the butterfly emerges, with all its features, both external and internal fully developed The new cuticle is still soft, and the wings folded and crumpled The insect clinging to the pupal cuticle or to any other convenient object, remains quiet until the wings expand fully and the cuticle hardens thoroughly all over the body, and the insect is able to take to its wings.

The adult, unlike the larva and the more generalised insects like the cockroach, has highly modified mouth-parts. There is no mandible or only a feebly developed one and the first maxillæ are elongated and grooved, so that they, apposed to each other, form a tubular coiled **proboscis** (Fig. 97, B) so characteristic of the butterflies and moths and used for sucking the nectar from flowers The **wings** are large and membranous and covered with a fine powdery stuff which under the microscope is seen to be little scales which are responsible for the colouration of the insect The name Lepidoptera is given to the order of insects to which the butterflies and moths belong on account of the scales, the term meaning scaly-winged. The **legs** are very feeble and the abdomen is slender The **antennæ** are long and club-shaped

A butterfly does not feed, since it is full grown when emerging from the chrysalis and it has stored up a sufficient amount of nutriment in its body during the larval stages, which has only to be kept moist by sucking up moisture usually in the form of nectar.

(125) *Sketch the butterfly.*

(126) *Sketch the scales of the butterfly under the microscope.*

SOME USEFUL INSECTS

319. The Silk-Moth.—Several moths pupate in a cocoon of silk-thread spun from a viscid secretion of certain glands opening on the 'tongue' of the caterpillar. When drawn out into a fine thread the secretion hardens and forms silk, which is chemically the same substance as chitin which forms the external skeleton of insects.

There are three different silk-moths which may be noted. The first is the mulberry silk-worm, *Bombyx mori*, a highly domesticated species whose original home is believed to be China Silk is at present a staple industry in many districts of India and in China, Japan, Italy and France. The entire cocoon is made of a single reelable thread, which is broken into bits by the emergence of the imago Cocoons meant for silk have therefore to be 'stifled' or killed by heat. The end of the thread is then teased out and four or five together are reeled on to a spool, the cocoons floating in a dish of water Cocoons intended for rearing purposes are kept separately, and scrupulously cared for. After oviposition, the moth's body is examined microscopically and if parasites are detected, the eggs are destroyed, since the larvæ bred from them would be already infected in the egg-stage and precipitate an epidemic which may involve the industry in considerable loss and damage (See Sect. 189)

The Eri silk worm is fed on the leaves of castor. Its silk is not reelable and therefore the split cocoons from which the moths have emerged can be used for purposes of manufacture, the threads being spun like cotton. The Tasar silk-worm is a wild species, producing a reelable cocoon, from which Tasar silk is manufactured

320. Other Useful Insects.—Next in importance among useful insects is the honey-bee There are three species common all over India of which *Apis indica* is cultivated in apiaries all over the country. Besides providing honey, bees are extremely useful to the farmer as they play an important part in the pollination of his crops

Lac is a resinous secretion of certain scale insects (related to the bugs) which live a parasitic life on certain plants Blister-beetles produce a substance called cantharidin, used in medicine. Termites and locusts are eaten by the poorer people in certain districts of the country. A good part of the food of the domestic fowl and other birds consists of insects and insect larvæ.

REVISION QUESTIONS

237 How can you distinguish the sex of a cockroach by mere external examination?

238. Where are cockroaches usually found? Is the depressed shape of their bodies of any advantage to them?

239 Account for the fact that cockroaches are found in very large numbers in human habitations

240 What is the food of a cockroach? How are its mouth parts adapted for feeding?

241 What is the characteristic odour of the cockroaches due to?

242. In a collection of cockroaches, we usually meet with a few full-grown ones without wings If a number of cockroaches are left, say, under a bell-jar, one may often find that some have turned white overnight Explain these

243 Compare the leg of an insect with that of a vertebrate How does the disposition of the muscles of the two groups of animals differ from each other?

244 Is the cockroach metameric in its organisation? If so, what are the parts of the body which display metamerism distinctly?

245 Compare the external features of a caterpillar with those of an earthworm

246 What is a larva? What do you understand by the term metamorphosis?

247. Compare the life-history of a cockroach with that of a butterfly or of a mosquito

248 How does the respiratory mechanism of an insect differ from that of other animals you have studied?

249 Compare the mouth-parts of a cockroach with those of the caterpillar and the butterfly

250 The adult butterfly needs very little food except nectar The silk-moth does not possess a proboscis and cannot therefore feed at all. Explain

251 How far do you consider the cockroach to be a pest? Does it serve any beneficient role in our houses?

CHAPTER 30

CLASS INSECTA (Contd)—LIFE-HISTORY OF MOSQUITO—ORAL APPENDAGES OF ANOPHELES—CULEX AND ANOPHELES COMPARED—INSECTS AND DISEASE—THE HOUSE-FLY—ITS STRUCTURE, LIFE-HISTORY AND HABITS—PROTECTION FROM FLIES—DISEASES SPREAD BY THE HOUSE-FLY—CHARACTERS AND CLASSIFICATION OF ARTHROPODA

Material for Study Collect stagnant water, from any puddle in which organic matter is decaying, in a small glass basin If mosquito larvæ are present, they can be easily made out by their darting movements When the basin is at rest for a short time, the larvæ and pupæ can be seen hanging from the surface-film of water. Cover the basin with a bell-jar, the neck of which is closed with fine wire gauze Mosquitoes will emerge from the pupæ and collect inside the bell-jar, where their posture, etc , can be easily examined

In order to collect the eggs, leave over a second sample of the water in an open basin for a day or two Clusters of eggs in the form of rafts can be picked up from the surface of the water for examination

A few house-flies , micro-slides of proboscis and leg of the house-fly

321. Mosquito Eggs.—(Fig 98) The mosquito lays her eggs on the surface of water where she betakes herself immediately after mating The common gnat (*Culex*) arranges the eggs into a raft in which each egg is held vertically In the malarial mosquito (*Anopheles*), on the other hand, the eggs are laid singly and lie horizontally on the surface of the water, where they arrange themselves into patterns.

322. The Larva.—In two or three days the eggs hatch and very small, transparent larvæ emerge and begin an active, feeding and growing life They can be seen hanging from the surface-film of water for long intervals absolutely motionless The larva of *Culex* hangs head down at an angle from the surface-film by the end of a fairly long **respiratory tube** arising from the penultimate segment of the abdomen, while the larva of *Anopheles* is distinguished by the fact that it floats horizontally with the entire length of its body parallel to the surface film, and by having only short respiratory siphons In this position the larvæ are able to breathe directly from the atmosphere by a tracheal system opening out by the respiratory tubes. During a period of a fortnight or so of growth, the larvæ moult several times as in the case of a caterpillar.

(127) Sketch the larva under a lens.

323. The Pupa or Nymph.—At the last larval moult the shape has changed into that of the pupa, characterised by a large head-end and shaped like a comma It floats under the surface-film, head upwards unlike the larva, and breathing takes place by means of a pair of trumpet-shaped siphons arising from the dorsal side of the head. The organs of the adult, like the eyes, wings and appendages can be seen through the transparent pupal cuticle Like the larva it darts down into the depth of the water at the slightest disturbance, only to return to the surface in a short time, but it does not feed Within the pupal cuticle the reorganisation of the tissues resulting in the formation of the adult insect takes place, and after a few days of pupal life the cuticle bursts along the back, the adult escapes, first to the surface of the water for a brief interval and then into the air on its wings.

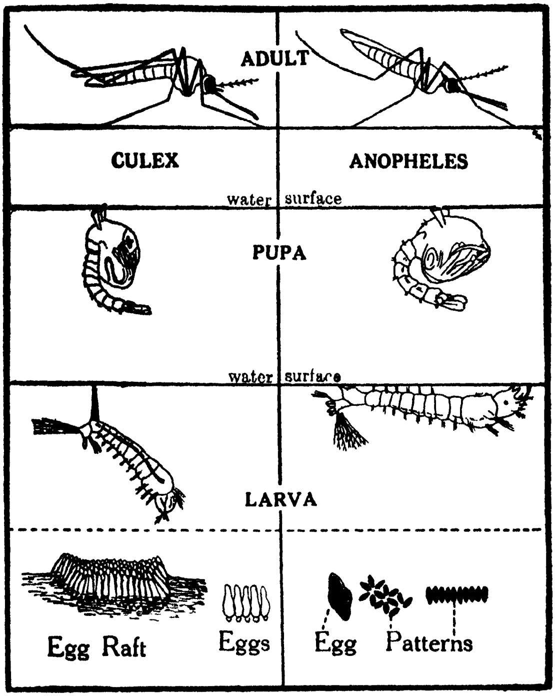

Fig 98 The life-history of *Culex* and *Anopheles*

(128) Sketch the pupa under a lens

324. The Imago.—Unlike the cockroach, the mosquito has but a single pair of wings These are the mesothoracic ones and are highly membranous The hind-wings, however, are reduced into a pair of '**halters**' which can be easily seen with the help of a lens. The three segments of the thorax are very much fused so as to appear large and swollen with a prominent ventral hump The mouth-parts show very great modification and are adapted for piercing the skin and sucking the juices of plants or animals. No growth takes place, as in the butterfly, active feeding and growing being confined to the larval stage.

(129) Sketch the adult insect under a lens

325. The Oral Appendages.—(Fig 99) Examine the head of a female *Anopheles* under the microscope. With the help of a pair of needles separate out the proboscis into its component parts.

Note the prominent compound eyes hexagonally facetted and the bushy multisegmented antennæ The **labium** (second maxillæ) forms a soft deeply grooved structure with a forked terminal joint Obviously the maxillæ of the right and left sides have fused into the single labium as in the cockroach In the hollow of the labium lie six elongated stylets used for piercing purposes. These are homologous to the remaining mouth parts of a typical insect like the cockroach, viz, a single median stylet, which is the modified **labrum** roofing over the groove of the labium, a pair of finely pointed stylets which are the **mandibles ;** a pair of pointed stylets with a serrated tip, which are the pair of **first maxillæ ;** and a single median stylet lying ventralmost in the groove, which is the elongated **hypopharynx** on which the salivary duct opens.

Practical work

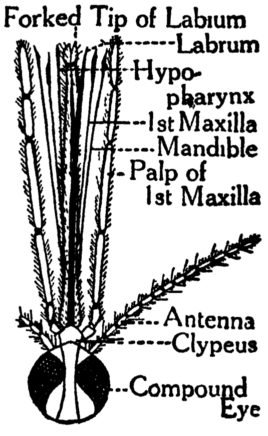

Fig 99 *Anopheles* Oral appendages of the female

The **palps** of the 1st maxillæ are very short in *Culex*, but in *Anopheles* they are as long as the labium. In both they remain distinct from the sucking tube.

In the male, the mandibles are absent, and the hypopharynx and the labium are fused into one.

It is only the female that bites human beings

(130) Sketch the mouth-parts under the microscope.

326. Culex and Anopheles.—These two common genera of mosquitoes can be easily distinguished Some of their differences are set forth in Table 10.

TABLE 10

MOSQUITO AND GNAT COMPARED

ANOPHELES (MOSQUITO)	CULEX (GNAT)
Wings spotted	Wings not spotted.
Maxillary palps long	Maxillary palps short.
Sits with the posterior end away from the sub-stratum	Sits with the body almost parallel to the sub-stratum
Larva with very long respiratory tubes	Larva with short respiratory tubes.
Larva hangs downwards from the surface-film of water	Larva lies parallel to the surface-film of water
Eggs laid singly and form patterns	Eggs arranged into a raft
Transmits human malaria.	Transmits bird-malaria and filaria

327. Mosquito Control.—Extermination of mosquitoes even from a limited area would be a stupendous task, even if it were practicable. Fortunately however, the keeping down of their numbers and therefore the peril of infection through them can be successfully undertaken by any house-holder in a mosquito-infested locality, taking advantage of the fact that they can breed only in water and of their inability to fly further than a few hundred yards He can see that all stagnant pools of fresh-water are drained or filled up and that no old tins, pots, etc , in which water may collect, are allowed to lie about the house. Even a hollow in the trunk of a tree holding water is a likey breeding place for mosquitoes He should replace open pit-latrines by more sanitary water-closets or septic tank latrines with a water-trap. Over larger stretches of water, not easily drained, he should pour some cheap oil, which would spread over it in a thin even film and prevent the larvae and pupae from breathing air. He can also stock them with minnows and other larvivorous fish (e. g., *Haplochilus*).

The only satisfactory method of protection from mosquitoes at night is the use of mosquito-nets.

328. Insects and Disease.—We have seen in Sect. 178 that mosquitoes of the genus *Anopheles* are the carriers of malaria. A number of other insects are at present known to be the intermediate hosts or casual disseminators of various disease germs. Not only man, but his domestic animals and food and other crops suffer from the ravages of insect pests, so that the good done by them as a class (Sects. 319 and 320) fades into insignificance before the drain on human life, productive capacity and effort produced by them.

The following is a list of the more important human diseases transmitted by insects:

TABLE 11

HUMAN DISEASES TRANSMITTED BY INSECTS

INSECT-GROUP	CARRIER-GENUS	DISEASE	PARASITE	LOCALITY
Mosquito	*Anopheles*	Malaria	*Plasmodium*	Asia, S Europe, Africa, S & Central America
,,	,,	Elephantiasis	*Filaria*	East Indies, S Sea Islands, Japan, India, Africa
,,	*Culex*	,,	,,	,, ,,
,,	*Stegomya (Aedes)*	,,	,,	,, ,,
,,	,,	Yellow Fever	(?)	West Africa, America
,,	,,	Dengue	Virus	Universal
Blood-sucking Fly	*Chrysops*	Eye-Worm Disease	*Loa loa* (Sect 264)	Spanish America
,,	*Glossina*	Sleeping sickness	*Trypanosoma*	Africa
,,	*Phlebotomus* (?) (Sand-fly)	Kala-azar	*Leishmania donovani*	India, Assam, China, Anglo-Egyptian Sudan
,,	,,	Oriental Sore	*Leishmania tropica*	East Mediterranean, S W Asia (incl India)
,,	,,	Papatasi Fever	Spirochaete	Mediterranean, W Asia, C India
,,	*Musca domestica*	Typhoid	Bacillus	Universal
,,	,,	Cholera	,,	,, ,,
,,	,,	Tuberculosis	,,	,, ,,
,,	,,	Amoebic dysentery	*Entamoeba histolytica*	Tropical Regions
,,	,,	Ophthalmia	(?)	Tropical and sub-tropical regions
Eye-fly	*Siphonella*	,,	(?)	,, ,,
Flea	*Xenoplylla*	Bubonic Plague	Bacillus	Tropical Regions

329. The House-Fly.—The very important, if nefarious, role of the house-fly, *Musca domestica*, in the transmission of disease together with its universal distribution and prolific nature, makes it worth-while to give some attention to its structure, life-history and habits. Unlike blood-sucking flies, the house-fly is incapable of piercing the skin and sucking blood or injecting microbes into our bodies. All the same, it is an even more dangerous insect as it is capable of carrying about its body and disseminating almost any kind of microscopic organism, including disease-germs and eggs and larvæ of parasitic worms and casually depositing them in places wherefrom they can have access to our intestines or blood-system

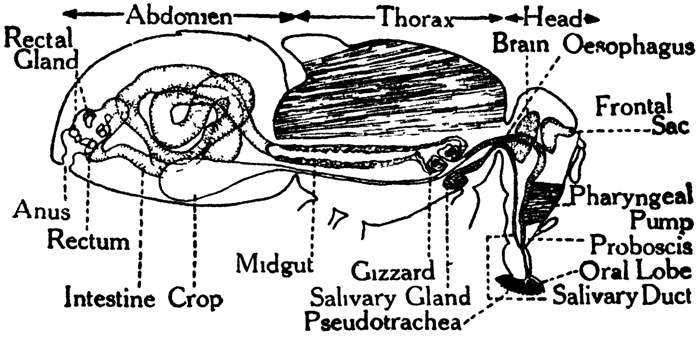

Fig 100 *Musca domestica* A sagittal section. (Altered from Hewitt)

330. Mouth-Parts.—(Fig 100) These are different from those of any of the other insect seen above, even the mosquito, though both belong to the same order, viz Diptera, characterised by the presence of only two wings, the posterior pair being reduced to 'halters'. The **proboscis,** homologous with the labium, of the mosquito, here forms a complete tube, terminated by a pair of soft cushion-like **oral lobes**, together forming a heart-shaped structure, with the aperture leading into the mouth situated between them On the inner side of each of the oral lobes are about thirty open channels called **pseudotracheæ.** These lead into a main channel situated on the median edge of the corresponding oral lobe. The two main channels open into the **mouth.** The mouth leads into a pharynx provided with powerful muscles forming a pharyngeal pump, by means of which the fluids on which the animal feeds are sucked up the grooved channel-system just described.

The two valves of the oral lobe can be closed and the whole proboscis bent and tucked under the head when not in use.

(131) Sketch the proboscis of the house-fly under the microscope

331. The Alimentary Canal.—(Fig. 100) The pharynx is continued up into the oesophagus, which passes through the oesophageal nerve ring including the brain and sub-oesophageal ganglion, and reaches the thorax where it opens into a muscular **gizzard** (proventriculus), followed by the chyle stomach or **mid-gut.** Before opening into the gizzard, the oesophagus gives off a long terminally dilated crop lying ventrally in the greater part of the length of the thorax and abdomen and serving as a reservoir for food The mid-gut is continued in the abdomen as the coiled intestine, marked into two parts by the insertion of the Malpighian tubules The hinder end of the intestine is continued into the rectum, which opens externally by the anus. The rectum contains two pairs of rectal glands of uncertain function.

332. Life-History.—The house-fly breeds throughout the year, provided the necessary environment, viz , warm, moist weather and any kind of decaying organic matter From one hundred to eight hundred eggs are laid by the female at a time The rapidity of development, the large number of eggs laid, the ability of the same fly to lay several batches of eggs in the same season, and the very short time required for the imago to attain sexual maturity, combined with the abundance in which stable-manure, night-soil and such other congenial media for the feeding and development of the fly can be had, make it one of the most prolific of insects

The eggs are deposited in a convenient dark place by the protrusible ovipositor, a modification of the last few segments of the abdomen, in stable manure or any other kind of garbage The **maggots,** as the larvæ are called, hatch out in eight to twenty-four hours, depending on the temperature, development being rapid at higher temperatures. They feed on the medium in which the mother has deposited the eggs and grow rapidly, moulting twice before reaching full growth, under favourable conditions, in five days. The maggot has a tapering body rather pointed in front and thick behind It is able to avoid light on account of two small sensory tubercles at the anterior end. When full grown the maggot measures half an inch in length Locomotion as well as foraging for food is assisted by a black hook-shaped process at the anterior end Locomotory pads on most of the segments placed ventrally also help in locomotion, which may be forwards or backwards Before pupating the maggot betakes itself to a convenient dry spot, often yards distant, comes to rest and draws in the anterior end so as to give rise to a barrel-shaped body The cuticle now turns dark-brown and becomes the pupal case or puparium In three to four days, the imago emerges pushing off the anterior end of the puparium in two parts with the aid of a frontal sac, afterwards withdrawn into the head (See Fig 100). Sexual maturity is reached in ten to fourteen days and eggs are laid four days after mating

333. Habits.—Universal in its distribution, cosmopolitan in its tastes, impartial in its attentions, there is no human habitation that is free from the house-fly Only inclement weather conditions exert a natural check upon their numbers Devices like fly-traps, fly-paper, etc , only help to call fresh reinforcements to the battle-front. The greatest danger from flies lies in the fact that a fly breakfasting upon filth in the manure-pit or latrine carrying hordes of microbes of all kinds including disease-germs, may choose a few hours later to lunch with the nearest human family, unceremoniously flitting from dish to dish, now sipping the milk and now vomitting out a tiny drop of poisoned liquid from its crop to dissolve a crystal of sugar before imbibing it. All over the body and particularly on the heavily setose legs (Fig 101) and in the contents of the crop are microscopic death-dealing bacilli of fell diseases such as typhoid, cholera or tuberculosis, cysts of Entamœbæ and the like, or eggs of parasitic worms of all kinds, mixed up with particles of filth Everywhere that the fly goes 'vomit-spots' and 'fly-specks,' the vomit and excreta of the fly, are left behind on vessels and victuals, which drying up, serve as potential sources of contamination at the next meal. In a country like India, where

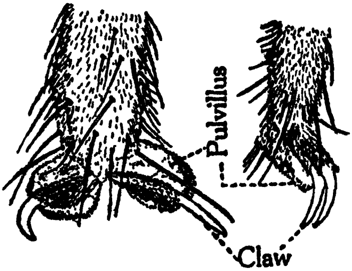

Fig 101 *Musca domestica* Terminal portion of leg, to show the highly setose nature of the appendages.

climatic conditions in most places permit the fly to thrive throughout the year the danger is all the greater

(132) Sketch the leg of a fly under the microscope.

334. Protection from Flies.—Inactivity of flies with falling temperature, their habit of shunning darkness (except for hibernation) and their inability to fly more than 500 to 1000 yards are factors upon which reliance may be placed in devising methods of protecting our food from their ravages Manure-pits and other favourite resorts of flies should be as distant as possible from human habitations and should be covered, both to prevent admission of flies and to ensure darkness inside Food should be stored in wire-meshed cup-boards and wherever possible kept at a low temperature. The house and surroundings should be scrupulously clean and no refuse should be allowed to lie about and decay, but must be deposited in a covered dust-bin or buried or burnt Kitchen utensils, plates, etc , should be well cleaned and kept covered. The same precaution should be adopted for water-pots Open wounds, ulcers, etc , should never be left uncovered.

335. Diseases spread by the House-Fly.—In addition to the diseases listed in Table 11, the microbes of which can reach a suitable nidus in the human body by other means as well, there are other diseases both of man and of domesticated animals for the transference of which the house-fly must be mostly held responsible In fact, there is no limit to the number of kinds of disease germs (which do not require some part of their life history to be spent inside the body of the insect) that the polluted body of the house-fly carries from place to place Microbes of cholera, dysentery, typhoid, diarrhœa, etc., taken into the intestine of the fly, are apt to remain alive and infectious and in the case of bacteria to multiply, making both its fæcal matter (fly-specks) and vomit (fly-spots) potential danger-spots By visiting ulcers, sore eyes, etc., of an infectious nature, flies are enabled to transfer some of the disease germs into congenial spots on the bodies of other animals and infect them with the disease. Thus flies are possible sources of contagion, not only of food and water-borne diseases, but also of others in which the infection is more direct, such as anthrax (in cattle), tuberculosis, oriental sore, ophthalmia, etc.

336. Characters of Arthropoda. — The Arthropoda are bilaterally symmetrical triploblastic animals showing segmentation of the body, with a firm external skeleton of chitin, paired jointed appendages (hence the name), some of which at the anterior end serve as jaws The coelom is mostly displaced by a blood-space or hæmocoel

337. Classification of Arthropoda.—The Arthropoda are classified into five classes

i. Class Onychophora. Arthropoda with a soft cuticular skin in place of the chitinous skeleton, breathing by trachea, with segmentally arranged excretory organs, well marked metameres with paired jointed appendages which are always uniramous The head bears three pairs of appendages, viz , a pair of antennæ, a pair of jaws and a pair of oral papillæ Only one genus, terrestrial *Peripatus*, a worm-like creature

ii. Class Crustacea Arthropoda with two pairs of antennæ, a pair of mandibles and two pairs of maxillæ carried by the head The head may be fused with some or all the segments of the thorax which follow behind, thereby forming a cephalothorax The appendages except the antennules (first antennæ) are typically biramous, the exopodite (outer ramus) being, however, often reduced or absent Fresh-water or marine, breathing by gills, and a few forms terrestrial breathing by trachea Examples ·—*Daphnia*, a water flea, fresh-water , *Lepas*, the goose barnacle , *Palæmon*, the fresh water prawn, edible , *Neptunus*, a common marine crab

iii. Class Myriapoda. Arthropoda with a distinct head, bearing paired antennæ, mandibles and first maxillæ Body segments numerous with uniramous appendages All genera are terrestrial, breathing by tracheæ. Examples .—*Aulacobolus*, the common black millepede *Ethmostigmus*, a common centipede

iv. Class Insecta. Arthropoda with a distinct division of the body into head, thorax and abdomen The thorax bears three pairs of appendages (legs), and often one or two pairs of wings Respiration tracheal. Young in most forms undergo a metamorphosis

The Insecta are one of the most predominant group of animals on the face of the earth, being the only invertebrates that are adapted for life in the air as well as on the ground and, a few in water.

The same variety of adaptations is found in their food, habits, methods of breeding, etc. As to numbers they easily beat all other animals combined Several groups of insects show a high degree of development of social instincts, e. g., the bees and termites. They play a very important role in the welfare of man, some being beneficial to him, while others are harmful pests or carriers of disease-germs. Examples —*Periplaneta*, the cockroach, with generalised mouth-parts , *Poecilocerus*, a common grass-hopper , *Cimex*, the bed-bug , *Dactylopius*, a plant-louse , *Odontotermes*, a common termite , *Culex* and *Anopheles*, mosquitoes , *Musca* and *Glossina*, flies , *Papilio*, a butterfly ; *Bombyx*, the silk-moth , *Oryctes*, the rhinoceros beetle , *Oecophylla*, an ant , *Apis*, the bee , *Eumenes*, a wasp.

v. Class Arachnida. Arthropoda devoid of antennæ, body divided into a cephalothorax (prosoma) and abdomen, the former bearing a pair of chelicere, a pair of pedipalps and four pairs of walking legs Respiration by lung-books in the vast majority which are terrestrial, and by gill-books in *Limulus*, a marine genus Examples — *Limulus*, the king crab, marine , *Palamnæus*, the common black scorpion , *Stegodyphus*, a common spider , *Sarcoptes*, the itch mite , *Ixodes*, the dog-tick.

REVISION QUESTIONS

252 What steps would you take to rid your surroundings of mosquitoes and house-flies ?

253 What precautions would you adopt against infection if you happen to live in a malarial district ?

254 Which is a more formidable enemy of man—Anopheles or Musca ? Why?

255 Compare the mouth-parts of a cockroach with those of the mosquito and the house-fly

256 Name as many common insects as you can Group them into the following categories Useful, Beneficient, Harmful

257 Mention the structural peculiarities of the house-fly which make it adapted for the life it leads

258 Compare the life-history of the mosquito with that of the house-fly

PART III—PHYLUM CHORDATA

CHAPTER 31

CLASS PISCES—EXTERNAL MORPHOLOGY OF SCOLIODON, A COMMON INDIAN SHARK—LOCOMOTION OF FISHES—CLASS REPTILIA—SNAKES—THEIR GENERAL EXTERNAL FEATURES—LOCOMOTION OF SNAKES—VENOMOUS SNAKES AND HOW TO IDENTIFY THEM—POISON APPARATUS—BITING MECHANISM OF A VIPER—CLASS AVES—EXTERNAL MORPHOLOGY OF COLUMBA, THE PIGEON—LOCOMOTION OF BIRDS—PERCHING MECHANISM

Material for Study Fresh or preserved sharks, a small live shark may be kept in a glass aquarium in sea water, where possible, a bony fish in an aquarium, museum specimens of rat-snake or grass-snake, cobra, krait, viper and sea-snake; a pigeon.

SCOLIODON, A SHARK

338. External Features.—(Fig. 102) Examine a shark. Note the fusiform body compressed in the region of the trunk, but depressed in the head, which ends in a snout. How does this shape help locomotion?

Note the position of the mouth, eyes, nostrils and gill-openings. How does the **mouth** differ from that of a bony fish? Both the upper and lower **jaws** bear one or two rows of sharp recurved teeth Since the mouth is ventral the animal has to turn over to one side in order to catch its prey The paired **eyes** are characterised by the possession of a nictitating membrane lying along the ventral side But for this, the eye-lids are not movable. The **nostrils** are placed in front of the eyes near the lateral edge of the snout A little behind the eyes are the five pairs of **gill-clefts.**

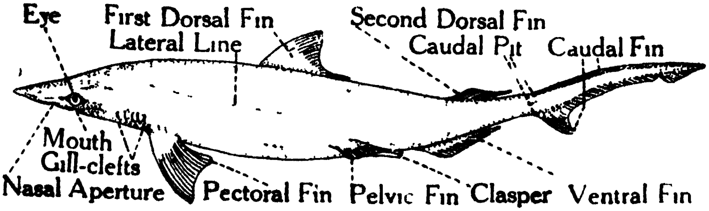

Fig. 102 *Scoliodon*, left side view

The appendages of the shark are the fins, both median and paired The **median fins** are the triangular **first dorsal** fin, placed a little in front of the middle of the body on the back, the **second dorsal** fin, midway between the first dorsal and the tip of the tail, the **caudal** fin consisting of a narrow dorsal lobe continued at the tip into the broader ventral lobe and the **ventral** or **anal** fin opposite the second dorsal

The **paired fins** are the pectoral and the pelvic fins. The **pectoral** fins are large triangular expansions arising ventro-laterally from the region immediately behind the head. The **pelvic** fins arise from the ventral side at about the middle of the length of the body They are much smaller than the pectorals and the **cloacal aperture** is placed between them. In the male, each of the pelvic fins has a **clasper** or copulatory organ along its inner edge

339. Dermal Denticles (Placoid Scales).— (Fig 103) Pass your finger over the body from the tail end forwards The roughness is due to the dermal denticles which project from the skin, slanting backwards

Practical work

Cut out a small piece of the skin from the shark and chop it up into small bits Put the bits into a 40% solution of caustic potash in a test-tube and gently warm the solution until the skin dissolves out When cool, fill with water and allow the dermal denticles to settle at the bottom. Decant several times till all the caustic and soft tisssues are thoroughly washed out. Transfer a small portion of the sediment on to a slide, cover with a cover-glass and examine under the microscope.

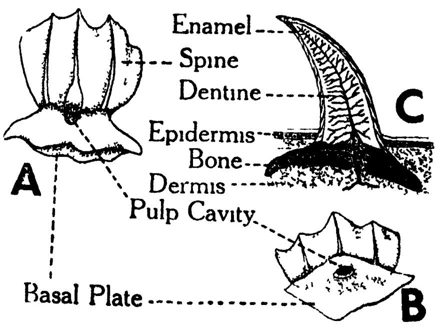

Fig 103 *Scoliodon*, Dermal denticles **A**, a denticle seen from in front, **B**, a denticle showing the rhomboid basal plate to advantage, **C**, longitudinal section of a denticle set in the skin, (× 70)

Each denticle is seen to consist of a rhomboid basal plate of bone embedded in the skin, bearing a usually trident spine consisting of a core of dentine (tooth-substance or ivory) and an outer layer of enamel. In the centre of the basal plate is an opening leading into the basal portion of the spine, where it enlarges into a pulp-cavity filled with blood-vessels, nerves, etc., derived from the dermis of the skin Minute canals are seen penetrating the dentine and bone These contain blood-capillaries arising from the pulp-cavity

In their natural condition the basal plates are firmly embedded in the skin and the spines piercing the epidermis project outwards and backwards in fairly regular oblique rows.

(133) Sketch the dermal denticles under the microscope.

340. Respiration.—Pass a seeker into the mouth and note that the pharynx opens to the outside through the gill-clefts. Each gill-cleft leads into a spacious gill-pouch, on the anterior and posterior sides of which are highly vascular mucous membranes thrown into close-set horizontal folds or **gill-lamellæ.** Between successive gill-pouches are the **interbranchial septa** which carry the lamellæ

Respiratory movements can be observed in a live shark at rest in an aquarium The floor of the buccal cavity is depressed, thereby increasing its volume The mouth is opened at the same time and water rushes into the buccal cavity and fills it Following this, the buccal floor is raised and the mouth is closed, while the branchial region is expanded drawing the water into the gill-pouches and out at the gill-openings

341. Neuromast Organs and Lorenzini's Ampullæ.—Examine the lateral sides of the trunk and make out the **lateral lines** extending from the tip of the tail to the back of the head where the two are connected together by a transverse supratemporal line, and thence continued on to the head as the cephalic The cephalic lines consist of a number of lines lying on the dorsal, ventral and lateral sides of the head, all connected together into one anastomosing system.

If a transverse section of the body is cut, say, across the tail, it will be seen that the lateral line is really a canal lying in the dermis. All along its length short tubes are given off from it and open on the outside by minute pores. Embedded in its walls are groups of epidermal sense organs called **neuromasts,** whose function is to enable the fish to detect wave movements in the water

Examine the snout and the sides of the head and make out the large number of pores arranged in symmetrical groups. Press the finger against one of the groups and note the jelly-like fluid oozing out, showing clearly that the pores lead from tubes lying deeper.

(134) Sketch the external features of the shark

342. The Bony Fishes.— The internal skeleton of the shark is made entirely of cartilage, while the bony fishes have their skeleton almost entirely made of bone Their scales, when present, are flat and overlapping The five gill-clefts are covered by an operculum or gill-cover on each side, so that there is a common branchial cavity into which the water escapes before passing out The tail is in most forms more or less symmetrical The pelvic fins are placed close behind and below the pectoral fins The mouth is terminal and instead of gill-lamellæ there are gill-filaments Sexual dimorphism is generally absent. Most bony fishes have a swim-bladder placed dorsally in their body-cavity and containing a gas The fish can secrete more gas into it or absorb some gas from it, reducing or increasing the specific gravity of the body This enables the fish to keep its position at any level without effort. The vast majority of marine fishes and practically all the fresh-water forms are bony fish

(135) Sketch the external features of a bony fish

343. Locomotion of a Fish.—Observe a shark or a bony fish as it moves about in an aquarium It will be clear that the tail is the most important locomotor organ, providing by its lateral flexion, followed by a quick and powerful backward stroke, alternately right and left, the force necessary for propelling the body forwards In a transverse section of a typical fish the body will be seen to be higher than broad, and this height is enhanced by the dorsal and ventral fins Every time the tail strikes forcibly backwards as mentioned above, there would be a tendency for the anterior end to sway sideways from the line of movement, and the purpose of the laterally compressed body and the vertical fins seem to be to counteract this tendency to side-slip The pectoral and pelvic fins may act as swimming organs only when the fish is moving very slowly, functioning like oars, when the tail is not used as a propeller Their usual function is to balance the body against any tendency to fall to the right or to the left

SNAKES

344. General Features.—In common with other reptiles--lizards, crocodiles and turtles—the snakes are characterised by a horny epidermal skeleton of scales covering the entire body, which is elongated and almost cylindrical, gradually or abruptly tapering in the tail. All snakes are devoid of paired limbs, but a few like the python still retain vestiges of the hinder pair in the form of minute pelvic bones and femurs together with a pair of claw-like spurs on the sides of the anus Unfortunately for the layman, it is not possible always to distinguish a snake from other groups of animals merely by the absence of limbs, for, there are fishes, amphibians and lizards that are limbless Snakes lack eye-lids, whose place is taken by a single watch-glass shaped scale that covers each eye. A limbless vertebrate with a dry scaly skin and devoid of eye-lids can at once be put down for a snake

Snakes invariably feed on an animal diet, insects, eggs, amphibians, other reptiles, birds or small mammals. Except in the burrowing forms, the mouth and gullet of snakes are extremely distensible, allowing them to catch and swallow living prey, often much thicker than themselves Hard, solid, pointed and recurved teeth strongly fused with the palatine and pterygoid bones as well as with the upper and lower jaws enable the snake to hold the prey firmly in the mouth and prevent its escape A bulky prey may be pushed back into the gullet by the independent, alternate, forward and backward movements of the paired tooth-bearing bones The prey is killed or paralysed in the venomous species either before or in the act of swallowing, according as the front or back teeth of the maxillary bones are the poison fangs As the prey is swallowed whole, it will take a longer or shorter interval to digest, and the snake, especially species that feed on larger prey, does not require to feed again during that interval

The **tongue** is a very important organ among snakes, used for a variety of functions All species possess the forked tongue which is frequently thrust out through a small hole between the upper and lower jaws (See Fig. 104, G) and retracted into a tubular sheath when at rest. The tongue makes a quivering movement, sweeping in a vertical direction with the tips expanded. It serves as a feeler, investigating the path of the reptile as it moves and as an organ of smell picking up the various odours in the air or on the ground. The nostril does not seem to be so important as the tongue as an organ of smell. The tongue is also used by several snakes to intimidate and in such forms it has vivid warning colours It may be mentioned that though the snakes possess ears there are no sound-receiving tympanic membranes.

The **glottis** in snakes is placed far in front and can be thrust further forwards. This is of advantage to an animal which has to hold a bulky prey in its mouth taking a long time to swallow it.

345. Locomotion.—A typical snake moves about on its belly which is covered by broad band-like scales with their free edges backwards, thereby offering a rough surface against the ground, allowing motion forwards and preventing any sliding back. These scales are moved forward by the ribs which are elongated and reach up to the ventral side, their tips being actually attached to the ends of the scale by connective tissue The movement of the ribs, in turn, is brought about by the contraction of the intercostal muscles. As the ribs are imbedded in the body-wall their movements are not visible externally. This accounts for the apparently effortless motion of the snake The intercostal muscles of the two sides of any region do not contract at once, but alternately, resulting in the characteristic undulations of serpentine motion

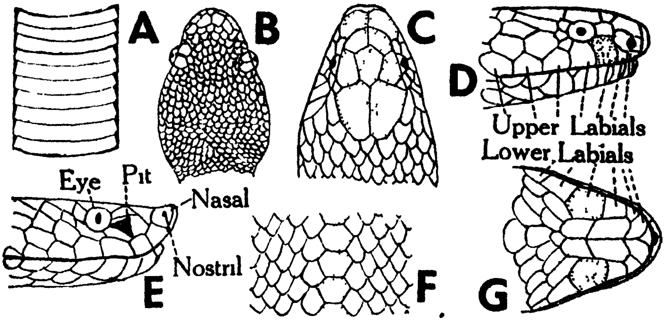

Fig 104 *Scalation of Snakes* **A** short length of belly showing transversely elongated scales, **B**, dorsal side of head of a viper with minute scales; **C**, dorsal side of head of a Colubrine snake with large shields between eyes; **D**, side view of same showing the seven upper labials **E**, side view of head of pit-viper, **F**, short length of back of krait showing the enlarged median scales, **G**, ventral view of head of krait showing the lower labials.

Several snakes show adaptations for particular types of locomotion, e. g, the arboreal ones have very long slender bodies or prehensile tails ; the marine forms have laterally compressed tails which function like the caudal fins of fish, and the burrowing forms have compact skulls with non-distensible mouths.

346. Common Venomous Snakes of India.—(Fig. 104) India is rich in its snake-fauna, but only a comparatively small number of genera are poisonous These are the cobras, kraits, vipers, pit-vipers and the sea-snakes. These can be easily distinguished with the help of the following key —

I. Tail laterally compressed . . . . . .Sea-snake, poisonous or non-poisonous

  1 Head with minute scales between eyes as in (B) . ...Non-poisonous

  2. Head with large shields between eyes as in (C) .... Poisonous

II Tail not laterally compressed Land-snake, poisonous or non poisonous

  1 Belly with small or slightly transversely elongated scales .Non-poisonous

  2 Belly with band-like scales extending right across ventral side (A) Non poisonous or poisonous

    i. Head with small scales between eyes (B) . Poisonous, Viper

    ii. Head with large shields between eyes (C) Non-poisonous or poisonous

      a. Third upper labial touching both eye and nasal (D) ....Poisonous, Cobra, King cobra or Coral snake

      b A pit between eye and nostril (E) . Poisonous, Pit viper

      c Back with middle row of scales enlarged and almost hexagonal (F) and 4th lower labial largest (G) .. Poisonous, Krait

347. Poison Apparatus.—The venomous snakes are provided with poison fangs and glands. The fangs are the enlarged maxillary teeth. When they are found at the hind end of the rather elongated maxillæ and are grooved for the conduct of poison, they are distinguished by the name opisthoglyphous. The **Opisthoglypha** or snakes possessing such teeth are but slightly poisonous and not fatal to man. If the poison fangs are at the anterior end of the elongate maxilla, and grooved for poison we speak of them as proteroglyphous The **Proteroglypha** are all deadly poisonous and lethal to man They include the coral snakes, king cobras, cobras, kraits and sea-snakes When the maxillæ are much shortened and bear only the poison fangs, which have the grooves closed in to form a canal, opening *near the tip*, but not at the tip, the arrangement is called solenoglyphous. The **Solenoglypha** have very large fangs, so large indeed that when not in use they are folded back and tucked under the roof of the mouth. They include the vipers and pit-vipers

The poison **glands** are paired, modified and enlarged labial glands, and have their ducts opening at the base of a pouch inside which the fang (or sometimes the two fangs) of the corresponding side lies. When the snake strikes, the mouth is opened and in closing it over the prey, the lower jaw is raised by the action of certain muscles, including the masseter Now, the contraction of the masseter presses upon the glands and squeezes the contained poison into the poison pouch, from which it flows down the groove or canal in the poison fang and thus gets injected into the wound cut by the fang

348. The Biting Mechanism of a Viper.— (Fig. 105) Of all snakes, the vipers have the most mechanically perfected arrangement for biting and injecting poison. As mentioned above, their fangs are canalled and serve as natural hypodermic syringes for the injection of poison. The great length of the fang enables the poison to reach deep down into the vital parts of the body, at any rate in the case of the smaller prey, which are instantly killed. When

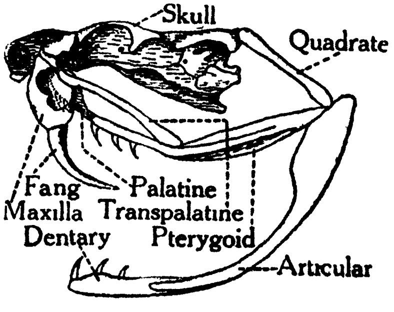

Fig 105 Left side view of the skull and lower jaw of a pit-viper, to show the biting mechanism

not in the striking attitude, the large fangs are accomodated by a special device. The maxilla is very short and bears only the poison tooth. It is movably articulated with the skull by a hinge-joint about which it can swing freely parallel to the sagittal plane. At the opposite end of the skull articulates the quadrate, which at its lower end gives attachment to the articular bone of the lower jaw, as well as the pterygoid. The latter is attached in front to the short palatine. Both the pterygoid and palatine carry teeth The pterygoid is slightly bent about its middle and stretching between the bend and the posterior side of the maxilla is the transpalatine bone. When the mouth is closed, the quadrate is nearly in line with the long axis of the skull and the maxilla inclined backwards so that the fang is laid back under the roof of the mouth. In the process of opening the mouth the quadrate has to be swung forward, and with it the pterygoid is pushed forward, causing the pterygo-palatine joint to be bent. The forward movement of the pterygoid is conveyed by the transpalatine to the maxilla and causes it to swing forward through about 90°, thus thrusting the fang forward into a position ready for striking

COLUMBA, THE PIGEON

349. External Features.— The dovecot pigeon kept in all parts of the country is a descendant of the wild rock pigeon (*Columba livia*). The domestic variety of this species is designated *Columba livia domestica*, the first name being the generic name, the second the specific and the third the varietal The wild rock-pigeon under domestication has given rise to a large number of form-varieties, such as pouters, carriers, tumblers, fan-tails, etc The colour varies widely in the domestic varieties, as is the case in domesticated animals generally, the wild ancestral species being slate-blue

An infalliable character of all birds is the presence of feathers, forming an exoskeleton, which in ordinary forms cover the whole body except the beak, tarsus and toes (See Fig. 106). The beak consists of an upper maxilla and a lower mandible which are covered in horny sheaths called **rhamphotheca.** The tarsus and toes are covered by horny **scales** similar to those of the snakes

Examine one of the primary **feathers** of the wing Note the quill continued distally into the rachis. On either side of the rachis is a vane or expanse of the feather composed of parallel barbs. Each barb bears two rows of barbules which hook themselves to barbules of adjacent barbs, thus helping to form a coherent plane, viz., the vane. The quill is hollow and the rachis is filled with pith (dead dry cells). This makes the feather extremely light.

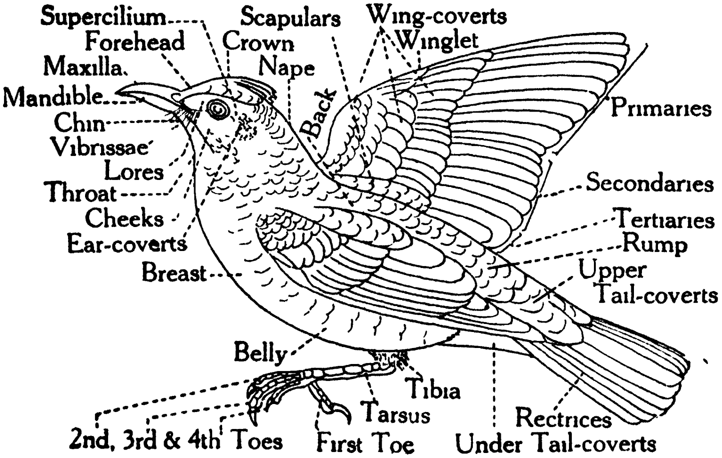

Fig 106 Nomenclature of the regions and plumage of a typical bird

Three principal types of feathers can be distinguished in the pigeon, viz , (1) **contour feathers** or the large feathers of the wings and tail and others of similar structure, (2) **down-feathers,** with a soft shaft and a vane without barbules and (3) **filoplumes,** with slender hair-like shafts and a few or no barbs.

(136) With the help of Fig. 106, make out the regions and plumage of the pigeon and sketch

Pluck the bird and notice that there are definite feather-tracts on the skin called pterylae, with naked spaces between or apteria

Note also the following the spindle-shaped body, covered by a rather loose, dry skin , the head, neck and trunk are well defined, and there is a short broad tail. At the base of the rhamphotheca is a patch of swollen skin called cere Behind it are the slit-like oblique nostrils. The eyes have upper and lower lids and a complete nictitating membrane. Just behind the eyes are the auditory apertures concealed by small feathers called ear-coverts. The mouth is a large opening between the upper and lower beaks and the cloacal aperture is a transversely elongated opening placed on the ventral side of the tail stump where it meets the trunk. On the dorsal surface of the tail-stump is a papilla on whose summit is the opening of a gland, the oil-gland, the secretion of which is used by the bird for preening the feathers

350. The Limbs.—Each **wing** consists of an upper arm, fore-arm and hand Only three imperfect fingers are made out in the hand, the first on the preaxial side, the second terminal and the third and smallest on the postaxial side The large flight-feathers including the primaries, secondaries and tertiaries spring from the postaxial border of the fore-arm and hand, and their quills pass through a broad ligament before getting inserted into the wing proper What is the advantage of this? Note the manner in which the feathers overlap one another—a manner calculated to give the maximum power to the down-stroke of the wing during flight A fold of skin, the pre-patagium, stretches between the upper arm and fore-arm along the preaxial side A similar but smaller one, the post-patagium, extends behind between the base of the upper arm and the trunk

The hind-limbs have the short thigh closely bound to the trunk and directed downwards and forwards The shank is much longer and directed downwards and backwards It is followed by the tarsus, covered by scales This is an elongated part containing inside a single bone called the tarso-metatarsus and ends in four toes, the first being directed backwards and the rest forwards Each toe ends in a claw

351. Flight-Muscles.—Lay the bird on a dissecting board, ventral side up and pin it down firmly by the outstretched wings and the neck Remove the skin from the ventral side. Note the large pectoral muscle on each side of the middle line. With a sharp scalpel, cut the muscle as close as possible to the bone (marked by the mid-ventral line), viz., the keel of the sternum. Note that the muscle fibres arise directly from the surface of the bone. In other words, there is no tendon of origin. Push aside the pectoral muscle and note its insertion at the anterior end on the ventral side of the humerus. Covered over by the pectoral is a more deeply placed, smaller muscle, the subclavius. Trace it forwards to its tendon, which will be seen passing between the bones of the shoulder girdle on to the upper side of the humerus.

Practical work

Now release the wing on the side on which the dissection has been made. Pull alternately on the pectoral and subclavius muscles, in imitation of their natural contraction, and note how the former causes the down-stroke and the latter the up-stroke of the wing In proportion to the size of these two muscles the down-stroke in actual flight would be much more powerful than the up stroke

(137) Sketch

352. Flight.—The entire organisation of the bird has been modified so as to make it a heavier than air flying craft propelled by muscular energy. We have just seen the muscles that develop the power and how by their contraction the downward and upward strokes are effected The down-stroke is in reality a downward and backward stroke enabling the bird by the resistance offered to the air to move upwards and at the same time forward On the contrary the less powerful upward and forward stroke is made with the least possible resistance, as the wing is then held edgewise to the air In order to develop the large amount of energy required for flight, the flight-muscles are constantly fed with a plentiful supply of oxygenated blood by large pectoral arteries, and in order to ensure thorough oxygenation of the blood, there is not only a well developed pair of lungs, but also a system of air-sacs insinuating themselves between the viscera and in the marrow cavities of some of the bones These air sacs store up air during inspiration, and this air rushes out through the bronchial system of the lungs in expiration, enabling the blood to take up oxygen not only during inspiration, but also during expiration. The air-sacs also help to reduce the weight of the body, an end secured also by the extremely light feathers, the hollow or cancellous bones and the large volume of air imprisoned among and under the feathers Extreme rigidity and great strength, so necessary for a flying craft, are secured by the fusion or overlapping of bones in several parts of the skeletal frame The non-conducting feather coat enables the bird to maintain a high temperature, necessary for developing the enormous energy required for flight, even when moving swiftly through extremely cold air. The tail with its large rectrices forms an efficient steering gear. Bending the tail downwards would cause the whole body to sink and elevating it to rise in the air. Tilting the tail sideways provides lateral steerage. Besides, the tail with the feathers fully expanded considerably augments the planing surface provided by the wings

353. Perching Mechanism.—A bird flying at a great speed can alight on the branch of a tree without putting on the brakes violently, and at the same time without being thrown forward and falling over. This it is enabled to do on account of special modifications in the muscles and tendons of the hind-limb The bending of the mesotarsal joint (between the shank and tarsus) brings about a simultaneous pull upon four tendons passing under the toes, causing them to grip firmly over the perch, the first toe going behind and the other three in front In the sitting posture this pull is maintained, the mere weight of the bird acting downwards, so that a bird can go off to sleep on the branch without fear of falling.

REVISION QUESTIONS

259 Compare the external features of a shark with those of a tadpole

260 Describe the structure of a vertebrate tooth Point out its resemblance to the dermal denticle Is there any difference between the dermal denticles and the teeth of the shark?

261 How can you distinguish between a male and a female shark? Is there any sexual dimorphism in the bony fish?

262. How do the external features of a bony fish differ from those of a cartilaginous fish like the shark?

263 Is there a lateral line (neuromast) system of sense organs in the tadpole? Are they present in the adult frog? What do you think is the function of these organs?

264 What do you know about the habits of the sharks? Considering the nature of their teeth, what do you think their food consists of?

265 An inner ear with membranous labyrinth is present in the fish and snakes, but there is no tympanum How do you account for this?

266 The lens of the eye of aquatic vertebrates is round, while that of terrestrial ones is biconvex Account for this

267. To what organs of the frog do the paired fins of a fish correspond?

268 What are the adaptive modifications undergone by the vertebrates in their transition from an aquatic to a terrestrial life?

269 What are the distinguishing features of the reptiles? How can you tell a snake from a limbless lizard?

270 Which are the commonest poisonous -snakes of India? How can you distinguish them from non-poisonous genera and from one another?

271. Mention a few snake-like animals outside the Class Reptilia Compare their habits with those of the snakes? Is any of them poisonous?

272. What is the advantage to the snake of the following?—the forked tongue, the forward position of the glottis, the distensible mouth, the recurved teeth, the independently movable tooth-bearing bones in the roof of the mouth, the long body, the smooth overlapping scales,

273 Describe the biting mechanism of a viper

274 Locate the the elbow and the knee-joints in the plucked pigeon.

275 Compare the egg of a frog with that of a bird

276 How do birds differ from reptiles in the care bestowed on the young?

277 Mention the diagnostic bird-characters seen in the external features of the pigeon

278 Explain why birds as a class show very little variation in structure, unlike the reptiles which have diverged into forms so different as the lizards, snakes, crocodiles, turtles, etc

279. Mention the flightless birds known to you

CHAPTER 32

CLASS MAMMALIA—EXTERNAL FEATURES OF ORYCTOLAGUS (LEPUS) CUNICULUS, THE RABBIT—BUCCAL CAVITY—TEETH OF RABBIT AND MAN—STRUCTURE OF TOOTH—ABDOMINAL VISCERA OF RABBIT—ORGANS OF THE THORAX AND NECK OF RABBIT—HUMAN STOMACH AND INTESTINES—INTERNAL STRUCTURE AND HISTOLOGY OF THE ALIMENTARY CANAL

Material for Study Live and killed rabbits, skulls of frog, rabbit and man; t s. stomach and intestine of any small mammal

354 The Rabbit, a Mammal.—The rabbit belongs to the class of animals known as the Mammalia Together with the fishes, Amphibia, Reptiles and Birds, they constitute the great sub-phylum of the animal kingdom known as the Craniata or Vertebrata (See Sect. 203) All mammals are characterised by certain easily noted and infalliable characters such as the possession of hairs and the possession of mammary glands for feeding the young. As we proceed with the structure of the rabbit, other mammalian characters will be noted. The common quadrupeds and man are also mammals

355. External Features of a Rabbit.—These are best studied in the laboratory with the help of a few specimens, live and killed. Note that the colour is not uniform in the different individuals. In the wild hare, a closely related species, all the individuals have the same dull brown colour As a rule, domesticated animals such as the rabbit, dog, cattle, etc , tend to show variations in colour and other features. On the other hand, in the wild condition, the tendency is towards uniformity (cf. Sect. 349).

Locate the external openings of the body, the mouth, nostrils, anus and the urino-genital opening. The mouth is bordered by an upper and a lower **lip,** muscular organs peculiar to the mammals The nostrils are placed at the tip of the snout and close to the mouth-opening. Whereas in the frog, reptiles and birds there is one common cloacal opening, in the mammal there are separate openings for the elimination of the alimentary waste, viz, the anus, and for the urine and genital products, viz, the **urino-genital opening.** The two are placed close to each other at the hind end of the body under the tail, the anus being immediately dorsal to the urino-genital opening. The space between the two openings is called the **perineum.** On each of the lateral sides of the urino-genital opening is a hairless depression of the skin on which the ducts of the perineal glands open. Their secretion has a strong and characteristic odour Examine an adult male and an adult female and note the differences between the two sexes In the female, the urino-genital opening is a vertical slit called the **vulva.** Besides, on the ventral side of the trunk are paired **teats** on which open the ducts of the **mammary glands.** In the male, the urino-genital opening is placed at the tip of the **penis** and on either side of it is a **scrotal sac** The pair of testes are placed inside these sacs.

Unlike the frog, the eyes do not project from the surface There is an upper and a lower eyelid, both movable, in addition to a nictitating membrane which can be drawn over the eye How does the latter differ from the corresponding organ of the frog? The outer ear or **pinna** is characteristic of mammals In the rabbit it is very highly developed and can be turned in different directions. Note the ear-pit or **auditory meatus,** at the bottom of which the tympanic membrane is placed. How does this differ from the arrangement in the frog?

The body is divisible into the head, neck, chest or thorax, abdomen, and tail. The presence of a neck enables the animal to turn the head about in all directions In the trunk, the thorax is marked off from the abdomen by having its walls strengthened by the ribs and sternum

Note the resemblance between the fore- and hind-limbs of the rabbit. Also compare them with the limbs of the frog. Count the number of digits in the hand or manus and the foot or pes. Note the **claws.** What is their use?

The possession of **hairs** is the most characteristic of all mammalian features. They are ectodermal in origin and consist of horny cells derived from the stratum corneum. Hairs cover the entire body of the rabbit including the palms and soles.

Note the eyelashes on the edge of the eyelids and whiskers or vibrissae on the snout, both of which are specially well developed hairs. What are their respective functions?

356. The Buccal Cavity of the Rabbit.—(Fig. 107) Force open the mouth of a killed rabbit and cut through the cheeks and the angles of the jaws on both sides Open the mouth wide and keep it in that position by means of a stick held between the jaws on one side Note the palate which is divisible into the anterior **hard palate** raised into transverse ridges, and the posterior **soft palate** ending behind in a free border or flap called the **velum palati** or **uvula.** On either side of the velum palati is a **tonsil.** The paired **naso-palatine canals** open close behind the upper incisors and communicate between the mouth and nasal cavities The **internal nostrils** are continued backwards to

Practical work

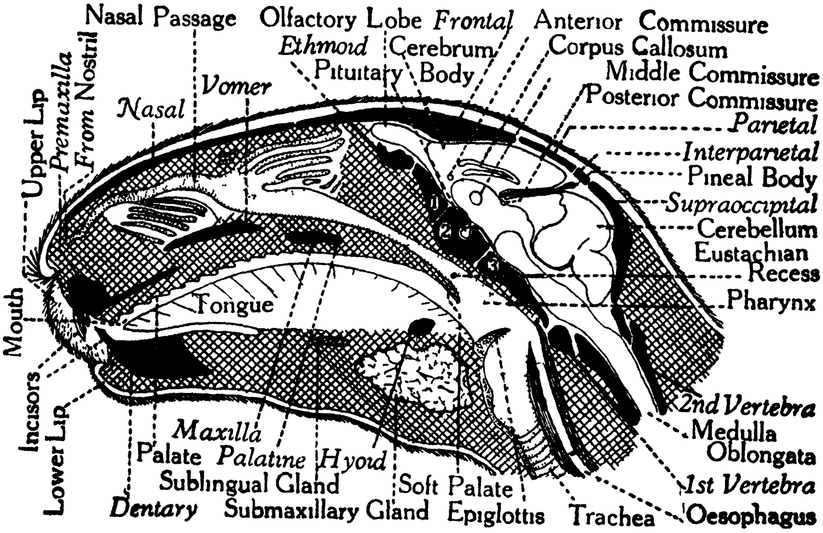

Fig 107 A sagittal section of the head of the rabbit 1, 2, 3, the presphenoid, basisphenoid and basioccipital respectively, names of other bones in italics

form the posterior **nasal chamber** or naso-pharynx at the sides of which open the **Eustachian canals.** The posterior nasal chamber is separated from the buccal cavity by the velum palati. The two chambers open into the common **pharynx** behind the level of the velum palati. At the hind end of the pharynx are two openings, the **oesophagus,** dorsal and the **glottis,** ventral. The latter has, arising from its anterior margin, a lid, called **epiglottis** which closes over it in the act of swallowing. The **tongue** lies on the floor of the mouth to which it is attached along the whole of its length, except the anterior free flattened tip.

(138) Sketch the wide open mouth of the rabbit.

The human buccal cavity is similar to that of the rabbit in essentials, but it is comparatively shorter in its antero-posterior extent. There are no naso-palatine canals opening into the mouth

357. Teeth.—Examine the skulls of a frog, rabbit and man In the frog the maxillary teeth are more or less uniform in size and shape (homodont), but in the rabbit and man you can easily see that the teeth are of various kinds (heterodont). Besides, their number is limited to 28 in the adult rabbit and 32 in adult man The heterodont dentition of a mammal most usually presents four kinds of teeth—incisors, canines, premolars and molars.

In the rabbit the **incisors** or front teeth are long curved, chisel-edged teeth used for gnawing. There are two pairs, an anterior and a posterior, in the upper jaw, and a single pair in the lower jaw Canines are absent, and there is a big toothless gap called **diastema** between the incisors and the **premolars.** The premolars are the first three pairs of cheek teeth on the upper jaw and the first two pairs on the lower. The remaining three pairs on each jaw are the **molars.** Note the rough surface of the grinders (See Figs. 124 and 125).

In man, the incisors are well developed and put to a variety of uses, from taking a bite off a banana to pulling out a nail The canines are present and provided with an obtuse point unlike the dog and other carnivorous animals in which they are large, strong, pointed and slightly recurved. Owing to the fore shortening of the human jaws and the presence of the canines, a diastema is altogether absent. The premolars and molars are similar in structure and function, the real difference between them depending on their relative position in the jaw and on the fact that, whereas the premolars of the young animal are shed and replaced by new ones in the adult, the molars appear in the adult only and are not replaced

Mammalian teeth differ from the teeth of lower vertebrates also in being implanted in sockets of the gum, i e., they are **thecodont** (See Figs. 108 and 124, B), and not fused with the jaw bones as in the lower groups, and in shedding but once or being **diphyodont,** whereas those of the lower forms shed several times and are replaced by new teeth The first set of teeth is called the **milk teeth,** and the second, the **permanent teeth.**

The nature and number of teeth of a mammal are expressed in the form of a dental formula, which in the rabbit is

$$\text{i. } \tfrac{2}{1}, \text{ c } \tfrac{0}{0}, \text{ pm. } \tfrac{3}{2}, \text{ m } \tfrac{3}{3} = 28.$$[*]

and in man.

$$\text{i } \tfrac{2}{2}, \text{ c } \tfrac{1}{1}, \text{ pm } \tfrac{2}{2}, \text{ m. } \tfrac{3}{3} = 32$$

358. Structure of a Tooth.—(Fig 108) If a tooth is sectioned longitudinally, we can see the various layers of which it is made The portion of the tooth projecting from the gum is called the **crown** and is covered by a thin layer of **enamel,** an extremely hard substance with but a trace of organic matter. The grinding surface, therefore, is capable of giving hard wear The outer layer of the **root** (the part of the tooth embedded in the socket) is coated with a layer of **cement** by which the tooth is firmly attached to the jaw-bone Inside the enamel and cement is a thick layer of **dentine** (substance of the tooth) forming the greater part of the tooth. Dentine is commercially known as ivory, and in teeth like the tusk of the elephant, etc., where it is obtained in considerable thickness, it is of econ-

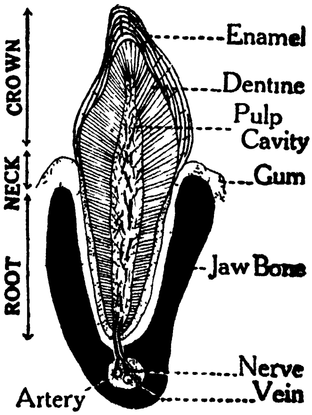

Fig 108 A cross-section of a mammal's jaw, through a tooth-socket showing a tooth in longitudinal section The cement is the layer marked by close-set fine dots in the root just outside the dentine (not labelled)

omic importance Excavated inside the tooth, forming the axis of the dentine, is a hollow or **pulp-cavity** which in life contains blood-vessels which supply the materials for the growth of the tooth, and nerve fibres which make it sensitive. In such teeth as stop growing after a time, as for example, the human teeth, the pulp-cavity is very much reduced, but in those like the incisors of the rabbit and the tusks of the elephant which grow throughout life, there is a large and persistent pulp-cavity

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[*] It will be seen that the figures above the lines give the number of teeth of each kind in one half of the upper jaw, and those below the number in one half of the lower jaw. The letters are the initials of the names of the four kinds of teeth

359. Dissection of the Rabbit's Abdomen.—Nail down the killed rabbit by the four limbs to a large dissecting board with the ventral side up Wet the ventral body-wall so as to prevent the hairs flying about and gaining access to the internal parts when the animal is opened Make a longitudinal incision of the skin along the mid-ventral line beginning at the pelvic region and ending at the snout Flay the skin all over the ventral side of the abdomen, thorax and neck so as to expose the muscular **bodywall.** Pin down the flaps of skin Note that there are no skeletal elements supporting the ventral wall of the abdomen, while the thorax is protected by the ribs and the sternum. Note also the absence of lymph spaces, so characteristic of the frog Now open the abdominal cavity by a mid-ventral cut of the bodywall and pin down the flaps

Practical work

Note the following —The abdominal cavity is separated from the thoracic by a muscular partition called **diaphragm** arching over the liver and the stomach Blood-vessels and the oesophagus penetrate the diaphragm and pass into the abdomen Note the five lobes of the **liver** (Fig 109), the **gall-bladder** lodged in the central lobe, the **hepatic ducts** and **cystic duct** from the liver and gall-bladder respectively, and the two uniting in the common **bile-duct** leading to the duodenum The **pancreas** is a diffuse gland lying in the mesentery in the loop of the duodenum. The **pancreatic duct** receives a number of tributaries from the various lobes and opens into the duodenum. Note that the bile and pancreatic ducts open respectively near the stomach-end and the ileum-end of the duodenum and not together as in the frog and in man.

(139) Sketch the liver and pancreas with their ducts.

Now unravel the **alimentary canal** (Fig. 109), by carefully tearing or cutting the **mesentery** by means of which it is held to the dorsal body-wall, and lay the whole length spread out on the right side of the rabbit Note the following · The **stomach,** which is more sac-like than in the frog, has a **cardiac half** and a **pyloric half** (which is which?) clearly marked. Between the two the oesophagus enters The pyloric half is continued as the duodenum. The **pyloric constriction** or sphincter marks the beginning of the small intestine of which the first and shorter part is the **duodenum** and the second and longer part the **ileum.** What is the length of each of these parts? The ileum ends in a small round sac **(sacculus rotundus)** The main canal is now continued as the large intestine consisting of the **colon,** the closely sacculated portion and the **rectum,** beaded with the pellets of faecal matter inside. The rectum ends in the anus, also marked by the anal sphincter. From the sacculus rotundus is given off also the large spirally constricted **caecum** ending blindly in a finger-shaped portion called the **vermiform appendix.** Note the lengths and diameters of the colon, rectum, caecum and vermiform appendix

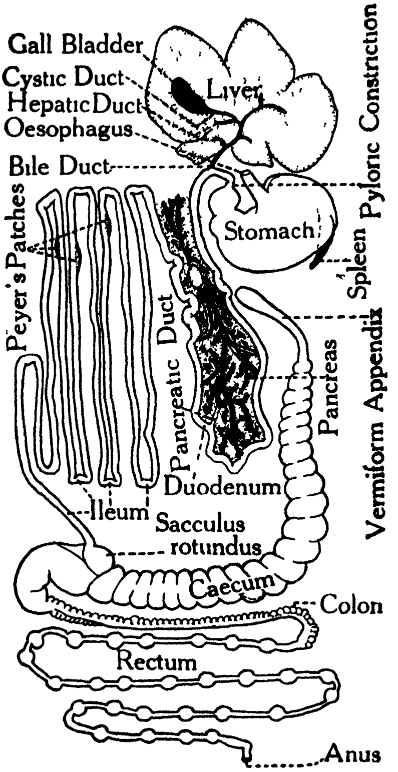

Fig 109 The abdominal portion of the alimentary canal of the rabbit with the liver and pancreas, the liver is pushed forwards to show the five lobes, gall-bladder and bile-duct

(140) Sketch the alimentary canal

360. Other Structures in the Abdomen.—Besides the digestive glands and the alimentary canal, the abdomen lodges the following: The **spleen** is an elongated gland lying attached to the cardiac portion of the stomach. The pair of **kidneys** are attached to the dorsal body wall, the right one being somewhat in front of the left. Lying between the kidneys are the great blood-

Practical work

vessels, the **dorsal aorta** and the **posterior vena cava.** On either side of them in the hinder half of the abdomen lie covered by the peritoneum the two **ureters.** Trace them on to the **urinary bladder,** a large pyriform muscular sac containing urine Towards the anterior and inner aspect of each kidney is a small, rounded, yellow **adrenal body.** In the adult male rabbit, the spermaries or **testes** can be seen on slitting open the scrotal sacs. In the young they lie close to the kidneys inside the abdomen. The **ovaries** are a pair of small ovoid bodies attached to the bodywall behind the kidneys. The **oviducts** will be quite conspicuous in the adult female.

(141) Sketch the abdominal viscera other than the alimentary canal.

Note A fuller dissection of the urino-genital organs will be made later (Sect 403) The hinder part of the abdomen of the rabbit dissected may be preserved for this purpose

361. Dissection of the Thorax and Neck of the Rabbit.—Open the thoracic cavity by cutting along its lateral walls As you cut note the **ribs** and the **intercostal muscles** stretching between the ribs in the form of a thin narrow sheet. Carefully note the attachment of the muscle on the outside and on the inside Do the intercostal muscles have tendons for attachment to the ribs like the larger muscles of the body? (See Sects 86 and 351). Try if you can separate out the external intercostal from the internal intercostal, and note that the fibres of the external intercostal pass from one rib to the next one behind obliquely backwards and ventralwards, while in the internal they are backwards and dorsalwards This arrangement, as will be seen later (Sect 378), aids in the expansion and contraction of the thoracic cavity while breathing.

Practical work

On removing the ventral half of the body wall, the **heart** and the pair of **lungs** come into view Note the **pericardium** which encloses the heart Carefully cut away the pericardium so as to expose the heart. Note the **ventricle** and the two **auricles.** Dorsal to the heart is seen the **œsophagus** penetrating the **diaphragm** behind. In front of the heart the **trachea** reaches the thorax and divides into a pair of **bronchii** entering the lungs. The **thymus,** a ductless gland, is a soft mass, looking like a fat body, below the base of the heart.

(142) Sketch the thoracic cavity and its contents

Along the mid-ventral line of the neck lies the **trachea,** easily marked by the series of cartilaginous rings embedded in its wall. Note that dorsally these rings are incomplete. Trace the trachea forwards to the **larynx** (Sects. 374 & 381), its dilated anterior end The ventral wall of the larynx is strengthened by a wide **thyroid cartilage,** and anterior to it is the epiglottis already seen. Behind the thyroid is a complete ring of cartilage called the **cricoid** On the sides of the trachea are two large blood-vessels placed immediately under the skin, viz., the **external jugular veins.** The **carotid arteries** are placed more deeply, on the inner side of the veins Below the trachea is the œsophagus The **thyroid** is a small ductless gland placed on the ventral side of the larynx

Practical work

(143) Sketch.

Cut off the heads of all the specimens dissected, skin them, expose the brain by a tangential cut of the roof of the skull, remove the lower jaw and preserve in 10% formaline When hardened for a fortnight, these can be used for the dissection and study of the brain

362. Alimentary Canal of Rabbit.—You have seen that the alimentary canal of the rabbit is a very long tube, the portion in the abdomen being very much looped and convoluted The length of the canal is proportionately greater than in the case of the frog It will be remembered that the tadpole has its alimentary canal reduced in length as it transforms into the adult stage The rabbit, which feeds purely on vegetable matter, also has a long intestine This is true also of most other herbivorous animals Again the rabbit's alimentary canal possesses a blind pouch, the cæcum, of considerable dimensions All mammals possess the cæcum, but it is enlarged, as in the rabbit, only in herbivorous animals What do these facts tell you about the relation between the nature of the food and the alimentary canal?

363. Human Alimentary Canal.—(Fig 110) The stomach is a wide sac with a dilated part towards the left called the **cardiac end,** and a narrower right half called the **pyloric end** The œsophagus opens into the former, while the latter is continued into the next portion called duodenum. A pyloric constriction separates the stomach from the duodenum. This constriction is a sphincter-arrangement for closing the stomach When the contents of the stomach are ready to pass into the duodenum, the sphincter relaxes and allows the half-digested food to pass into it The mucous membrane of the stomach is drawn up into a number of longitudinal folds or rugæ, and these help to increase the area of the lining of the stomach, and, consequently, of the amount of gastric juice secreted by the gastric glands.

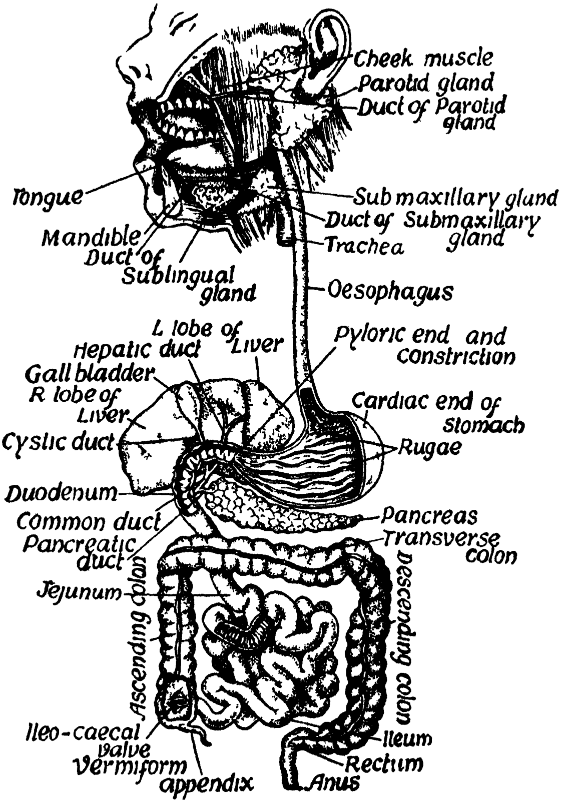

Fig 110 The Digestive system of man seen from the ventral (front) view The left cheek and the left half of the lower jaw are removed to show the salivary glands and their ducts The stomach, duodenum and portion of the intestine are exposed to show the folds of the mucous membrane. The liver is pushed backwards (dorsal-wards) slightly to show the gall-bladder and hepatic ducts The cæcum is exposed to show the ileo-cæcal valve

The **small intestine** is nearly 21 ft. long and is a tube of more or less uniform bore, very much coiled upon itself The first portion of it, viz., the one into which the stomach opens is the duodenum, about 10 inches long With the stomach it forms a U shaped bend in which the pancreas lies The duodenum receives the common duct along which the pancreatic juice from the pancreas and the bile from the liver pass into its lumen. The next portion is called the **jejunum,** 8 ft. long. It is redder than the duodenum, as there are a larger number of blood-vessels in its walls. It is followed by the **ileum,** 12 ft. long and thrown into coils It ends in the large intestine.

The **large intestine** consists of two parts, the colon and the rectum. The diameter of the colon is much larger than that of the ileum. It is sacculated and forms three sides of a rectangle, inside which the small intestine lies coiled up The first part has been called the ascending colon, the second the transverse colon and the third the descending colon The last of these is continued as the rectum. The rectum is 9 inches long and almost a straight tube, its diameter being considerably smaller than that of the colon. At the beginning of the ascending colon and projecting into it are two folds of mucous membrane so disposed as to prevent a reflux of food-matter back to the small intestine These folds form the **ileo-cæcal valve.** The other end of the large intestine is the **anus** opening to the outside.

The **cæcum** is a pouch situated below the junction of the small and large intestines Compared with the rabbit and most other herbivorous mammals it is very short. From its end arises a blind finger-shaped tube, the vermiform appendix, the inflammation of which causes appendicitis

364. Structure of the Alimentary Canal.—On slitting open the lumen of the alimentary canal of the rabbit, it will be seen that the different parts have their mucous lining differently modified In the stomach, as already noted, there are longitudinal folds or rugæ, while in the duodenum the folds are transverse and have the effect, not only of increasing the surface in contact with the food, but also of preventing a too rapid passage of food along the tube In the intestine the entire surface is covered with minute finger-shaped processes called **villi** (Sect 371) Interspersed with the villi are round or ovoid areas of glandular tissue known as **Peyer's glands,** distributed singly, or in groups called **Peyer's patches** (Fig 109). In the colon there are no villi, but only small papillæ, and the lining of the rectum is altogether smooth

The microscopic structure of the alimentary canal is best studied by means of transverse sections of the intestine and stomach of any small mammal, e g , the rat. It will then be seen to consist of the same tissues and layers as in the frog (cf Sect. 65)

As in the frog, the peritoneum envelopes the entire length of the alimentary canal, and forms a mesentery dorsally by means of which it is attached to the dorsal body-wall. The blood-vessels which enter and leave the alimentary canal lie between the two folds of the mesentery. The peritoneum secretes a watery fluid and is therefore called a serous membrane The fluid helps to lubricate the surface of the gut and prevent friction of one part upon another. The muscular coat comes immediately under the serous membrane and consists of two layers, the longitudinal (outer) and the circular (inner). In the stomach there is also an oblique layer inside the circular The contraction of the longitudinal fibres results in the widening of the lumen of the alimentary canal, while that of the circular layer has the opposite effect The connective tissue layer underlies the muscle layers and is also called the areolar or submucous layer The nerves, blood-vessels and lymph-spaces of the gut lie in the connective tissue. The mucous membrane is the innermost layer It is soft and slimy to the touch, and thrown into folds as seen above It consists of an epithelium of columnar cells, whose function is to secrete the mucus and certain of the digestive juices Hence the mucous membrane is a gland (cf. Fig. 122, A) Besides, it is the membrane through which the digested food permeates or diffuses into the sub-lying blood-vessels and lymph-spaces

(144) Sketch t s intestine and stomach under the microscope

REVISION QUESTIONS

280 How do you account for the following Wild hare have a uniform, protective colouration, adapted for the surroundings, while rabbits have varigated colours often quite conspicuous and not showing any adaptation to the surroundings?

281 How do the external features of the rabbit differ from those of the frog and man?

282 What is the advantage of each of the following to the rabbit? The nostrils are placed very close to the mouth opening, the vibrissæ are placed on the snout, the palms and soles are padded with fur, the upper lip is cleft, the hind-limbs are larger and more powerful than the fore-limbs, the claws are well-developed, the ears are large and movable

283 Enumerate the mammalian characters noted in this lesson

284 What is the use of the lips, in the young and in the adult? What is the function of the epiglottis?

285 Explain how the internal opening of the nose comes to be placed at the back end of the mouth? What is the advantage of this to an animal which chews its food?

286 What is the portion of the rabbit which corresponds to the roof of the mouth of the frog?

287 Enumerate those features of the rabbit you have noted so far which are particularly useful for terrestrial animals?

288 What is the use of the tail in the cow, the goat, the dog, the rabbit, the monkey, the lizard, the crocodile, the tadpole, the fish?

289 Compare the teeth of the rabbit with those of the frog, as regards, shape, arrangement, insertion, function and succession

290, Write down the dental formula of a child of ten and a boy of 16,

291. What are the structural adaptations you have made out in the buccal cavity of the rabbit for the particular kind of food on which it feeds?

292 What are the common rodents found in your part of the country? Are they considered to be useful animals or pests?

293 Enumerate the cervical, thoracic and abdominal viscera you have encountered in your dissection

294 How does the coelomic cavity of the rabbit differ from that of the frog?

295 What is the use of the intercostal muscles?

296. How does the respiratory system of the rabbit differ from that of the frog?

297 Why is the trachea strengthened by cartilaginous rings? Why are these rings broken opposite the oesophagus?

298 Enumerate the mammalian characters encountered in your dissection

299 The diaphragm is an arched muscular sheet attached to the body-wall all around What is the kind of movement that takes place when the muscles of the organ contract?

300 What are the structures that penetrate the diaphragm?

301 What are the various endocrine glands met with in your dissection?

302 Compare the alimentary canals of the frog, rabbit and man

CHAPTER 33

MAMMALIA (Contd)—HUMAN DIGESTIVE GLANDS -ENZYMES -FOOD —VITAMINS—DIGESTION —ABSORPTION—ASSIMILATION

365. Human Digestive Glands.— (See Fig 110) These include the salivary glands, the pancreas, the liver and the glandular epithelium lining the alimentary canal Each has its own part to play in the digestive processes, besides other functions which may be altogether unconnected with digestion (see Sects 409 and 417)

The use of the **salivary glands** will be obvious if we try to imagine how difficult it would be to masticate food without something with which to moisten and soften it in the mouth Proper mastication of food requires a certain quantity of saliva to be mixed with it, and indeed the grinding teeth will be of little use without salivary glands, which are as peculiar to the mammals as the grinding teeth themselves. As will be seen presently, saliva has another use, viz, to act as a digestive fluid, and digestion, in the case of mammals, may thus be said to begin right in the mouth

There are three pairs of salivary glands in man, the parotids, the submaxillaries and the sub-linguals Each **parotid** is placed in front of the corresponding ear and pours its secretion into the mouth by a duct opening between the cheek and the upper grinders. Each **submaxillary** is placed under the corresponding lower jaw-bone, its duct opening between the gum and the front of the tongue below its free tip The two **sub-linguals** are placed close together and their ducts open along with those of the sub-maxillaries

The glands secrete saliva at all times, but the rate of secretion increases when food is placed in the mouth Even the sight or smell of food is sometimes sufficient to enhance insalivation which is brought about by reflex action

We have seen that the **pancreas** lies in the bend between the stomach and the duodenum It is less diffuse in man than in the rabbit, but is with difficulty distinguished from the masses of fat that may be found investing portions of the alimentary canal Several small ducts arise from the different lobes and run into a large pancreatic duct which opens into the duodenum Before opening it is joined by the bile-duct from the liver, while in the rabbit the two ducts open separately and wide apart. The pancreatic juice secreted by the pancreas is thus poured into the duodenum

The **liver** is a large, reddish brown organ placed in the abdomen closely against the concave surface of the diaphragm and held to it by a fold of peritoneum It is the largest gland in the body and weighs over 3 lbs It has a right and a left lobe, the latter being the smaller The hepatic ducts from the two lobes join to form a single duct, which is joined by a cystic duct coming from gall-bladder The gall-bladder stores away the bile which is secreted continuously and sends it to the duodenum when necessary The cystic and hepatic ducts joining together give rise to the common duct opening into the duodenum along with the pancreatic duct

Of the glandular epithelia lining the alimentary canal, that of the stomach or gastric epithelium and of the small intestine are the most important in connection with digestion

Gastric glands are tubular involutions of columnar cells into the submucosa of the stomach (Fig. 24, B). The gastric juice secreted by the glands is poured directly into the stomach and mixes with the food in it. It is secreted only when food is in the stomach.

The **intestinal glands** consist of small tubular glands or **crypts of Lieberkuhn** situated between the villi or minute finger-like projections arising from the lining of the intestine (see Fig. 111). In the duodenum they are known as **Brunner's glands.**

366. Enzymes.—The digestive juices secreted by the digestive glands contain certain active principles which have been called enzymes or ferments For example, the saliva contains the ferment ptyalin which has the power of converting starch into sugar Now starch is a substance that does not dissolve in water or but slightly. On the other hand sugar is highly soluble, and can therefore easily permeate the mucous membrane of the alimentary canal In other words, it can be absorbed into the blood-vessels of the submucosa and thus passed into the general circulation of the body, whereas starch cannot What ptyalin does, therefore, is to convert an insoluble food-substance into a soluble one, in other words, it *digests* the starch.

Enzymes are organic compounds, usually fluid, capable of bringing about changes in other organic compounds while remaining unchanged themselves Their action, therefore, is that of a catalyst Their main properties are —(1) They are specific in action, i e, each enzyme acts on a particular class of food substance and on no other (2) They are reabsorbed after action or non-use (3) They are reversible in action, i e, if the action has been going on for some time and the digested products are not removed from the place of action, they will be reconverted into the original substance (4) This reversal takes place on reaching a point of equilibrium between the digested and undigested food. (5) Their action is usually one of hydrolysis (6) They have an optimum temperature, i e, they are most active at a particular degree of heat, above and below which their activity is reduced (7) They are destroyed by boiling

367. Food.—We have seen that digestion is a chemical change brought about by some ferment or other, resulting in the conversion of an insoluble food substance into a soluble one In order, therefore, to know something about the processes of digestion it is essential for the student to be acquainted with the *composition* of our food

Our food is a mixture of different substances, and w~~ea~~hether of animal or vegetable origin, it should contain six different classes of chemical compounds, viz., proteins, fats and oils, carbohydrates, mineral salts, water and vitamins. Of these the first three classes undergo changes of a digestive nature in the alimentary canal before they are absorbed, and are therefore referred to as the proximate principles of food in contrast to the others which are absorbed as such.

Protein is the only food-principle that contains nitrogen in addition to carbon, hydrogen and oxygen, and also usually sulphur and sometimes phosphorus Protein is highly complex in its chemical composition and is the most important principle in foods such as meat, eggs, milk, peas, grams, etc Proteins are essential for the repair of worn-out tissues of the body, for growth in the young, and to a certain extent for the formation of heat-energy They are insoluble in water Their approximate chemical composition by weight is —

C	53 parts	N	15 parts
H	7 parts	S	1 part
O	20 parts	others	4 parts,

in every 100 White of egg is a good example of protein

Carbohydrates contain carbon, hydrogen and oxygen, the last two being in the proportion in which they occur in water, hence the name They are the chief constituent of most vegetable foods, such as cereals, grains, etc , and of fruits Starch and sugar are more or less pure forms of carbohydrates They are the chief energy-producing food-principles Of these two, starch is insoluble in water, while sugar is soluble and consequently the digestive action of the alimentary canal on starch is to convert or hydrolise it into sugar

There are several kinds of sugars such as glucose or grape-sugar, fructose or fruit sugar, sucrose or cane sugar, lactose or milk-sugar, and maltose or malt-sugar (obtained from germinating seeds)

Starch is found in all cereals Dextrin, cellulose and glycogen are other forms of starch

Fats and Oils are compounds of carbon, hydrogen and oxygen, but the last two are not in the proportion in which they occur in water They are abundant in meat-foods, yolk of eggs, butter, cream, fish-oils, vegetable oils, etc They produce heat and a certain amount of muscular energy

Salts are of mineral origin, such as common salt, calcium carbonate, phosphates of calcium, magnesium, potassium and sodium and certain salts of iron. They play an important role in the osmotic pressure of the body and in the proper functioning of the nerves, muscles and bone Diseases such as anæmia, goitre, rickets, tetany, osteomalacia, etc , are associated with the deficiency of one or other of these salts in the system

368 Vitamins or Accessory Food-Factors.—These are very important food principles present in infinitesimal quantities in most fresh foods Their chemical composition is unknown They are essential for the maintenance of health and for growth, as is shown by the fact that animals fed on pure carbohydrates, proteins, fats and water will not thrive. When 'natural foods' as opposed to 'artificial' or synthetic are added to their diet, they thrive in a normal manner Absence of vitamins from the food leads to malnutrition, increased susceptibility to infection or even to the production of certain diseases which have been called 'deficiency diseases '

The knowledge of vitamins is very recent We know but little about them So far about six different vitamins have been discovered, though none has been isolated or chemically analysed

Vitamin A is a fat-soluble chemical substance, not destroyed by heat up to 200°C, but destroyed by oxygen and sunlight It is present in animal-fats like shark and cod liver oil and butter, green vegetables, etc It is necessary for the normally healthy condition of the mucous membranes Its absence from the diet causes certain disturbances of the mucous membranes of the respiratory, alimentary and ophthalmic organs, and renders the body suscpetible to bacterial invasion It is highly necessary during growth, pregnancy, and lactation

Vitamin B^1 is water-soluble and resists boiling in acid, but not alkaline media. It is found in fresh vegetables, yeast, meat, eggs and milk Its absence causes a disease called beriberi, an ailment in which the nervous system, blood-vessels and the intestinal tract are affected. It is common in countries where polished rice is preferred and its symptoms disappear when unpolished rice is substituted.

Vitamin B^2 is similar to B^1 and occurs in the same substances. Its absence causes a disaase known as pellagra.

Vitamin C is water-soluble and is destroyed by boiling in an acid medium in the presence of oxygen. It is found in fresh fruits and vegetables, germinating seeds and milk Its absence causes the disease called scurvy

Vitamin D is fat-soluble and is found in most animal oils. It is essential for the assimilation and utilisation of calcium and phosphorus in the building of bone Its absence causes rickets in children and osteomalacia in adults, both of which are associated with the softening and malformation of the bones

Vitamin E is fat-soluble and not affected by heat or light It is found in most vegetables, butter, meat, etc Its absence causes atrophy of the seminiferous tubules of the male and death of the foetus in the pregnant female

369. Digestive Juices and their Action on Food.—**Saliva** is a transparent, watery fluid, slightly alkaline in reaction and with a sp. gr. of 1 005, containing only 0·08 of solids in the form of salts and organic matter. In the mouth it is always mixed with mucus which makes it somewhat viscid The secretions of the three salivary glands are not identical, the submaxillary and sublingual glands secreting saliva rich in **mucin**, while the parotid does not secrete any mucin Saliva contains the enzyme **ptyalin,** which has the power of changing the insoluble starch into soluble sugar In the rabbit and other herbivorous animals, saliva is secreted in large quantities, as their food contains much starch The mucin helps to lubricate the food-balls in the act of swallowing

In children under about six months, the saliva has no digestive action. Nature does not intend that they should be fed on starchy foods till they have cut a few teeth.

Gastric Juice is, like the saliva, a clear, colourless fluid containing 2 5% of ' solids,' chief of which are pepsin, renin and hydrochloric acid. The last makes it strongly acid in reaction **Pepsin** converts proteins into soluble peptones and **renin** curdles milk. The hydrochloric acid has important functions like arresting the action of ptyalin on starch, dissolving the calcium carbonate contained in bone and other substances which form part of our food and destroying bacteria taken in with the food

From the stomach the partly digested and macerated food or chyme is sent into the duodenum It consists of partially dissolved starch and proteins, saliva, gastric juice, undigested fats, often in the form of globules liberated by the digestive action of pepsin on the fat-cells, mucus and any indigestible substances present in the food—all mixed with water to form a thick, viscid, milky fluid with a disagreeable odour.

Bile is yellow or greenish-yellow in colour and contains 16 parts by weight of solids in 100 parts These are bile-salts (10 parts), mucin and bile pigments (4 parts), cholesterol (1 3 parts) and salts (0·7 parts) Bile helps to emulsify fats, that is, break them up into minute droplets which can easily mix with water Being alkaline in reaction it prevents the action of gastric juice in the intestine and prepares the chyme (the semisolid mass of half-digested food that comes into the intestine from the stomach) for the action of the pancreatic juice Bile also contains bile-pigments, salts, and water which being waste materials have to pass out of the body with the faeces. Bile has an antiseptic action and checks the development of bacteria in the chyme

Pancreatic Juice is a colourless transparent fluid, alkaline in reaction and viscid in consistency. Its specific gravity is 1·004 and it contains 96% water and 2% solids Its alkalinity is due to the presence of sodium carbonate It contains three enzymes, viz, amylopsin, tripsinogen and steapsin Of these **amylopsin** acts on starch, converting it into sugar **Trypsin** is formed by the action of entero-kinase, a ferment of the intestinal juice on trypsinogen It converts proteins to amino-acids in an alkaline medium The alkalinity of the pancreatic juice enhances the emulsification of the fats already begun by the bile **Steapsin** acts on the emulsified fats and decomposes them into glycerol and a fatty acid, the particular fatty acid formed being determined by the particular fat acted upon The fatty acid decomposes the bile-salts and with their sodium base forms a soluble soap (or fatty salt). If there is any calcium or magnesium salt in the chyme, this will unite with the fatty acid and give rise to an insoluble soap which will not be absorbed.

Succus Entericus or intestinal juice is a yellow alkaline fluid of sp. gr 1·01, containing 1 5% solids, chief of which are its enzymes. It is secreted by the crypts of Lieberkuhn, and contains six different enzymes, one of which, **entero-kinase,** has already been noted Another is **erepsin,** which can act, not directly on proteins but only on peptones, converting them into amino acids Thus the work begun by pepsin in the stomach is completed by erepsin in the intestines. The other enzymes of succus entericus are **lipase, invertase, maltase** and **lactase.** Of these lipase decomposes neutral fats into fatty acids and glycerol, while invertase, maltase and lactase convert cane-sugar, malt-sugar (maltose) and milk-sugar (lactose) respectively into glucose.

TABLE 12

370. SUMMARY OF DIGESTION

DIGESTIVE JUICE	GLAND OF ORIGIN	REGION OF ACTION	NATURE OF MEDIUM	ENZYMES AND THEIR ACTION	OTHER USES
Saliva	Salivary Gland	Mouth	Alkaline	Ptyalin, converts starch to glucose	Lubricates food in mouth
Gastric Juice	Gastric Glands	Stomach	Acid	Pepsin, converts proteins to peptones Renin, curdles milk	HCl kills bacteria, dissolves $CACO_3$ and neutralises alkali of saliva
Bile	Liver	Duodenum	Alkaline	*Nil*	Alkali emulsifies fats Serves as lubricant and disinfectant
Pancreatic Juice	Pancreas	Duodenum	Alkaline	Trypsin converts proteins to amino-acids Steapsin, resolves fats into fatty acids and glycerol Amylopsin, converts starch to glucose	Alkali further emulsifies fats Fatty acid + sodium base of bile salts – soluble soap Fatty acid + calcium or magnesium base – insoluble soap
Succus Entericus	Glands of Lieberkuhn and Brunner's glands	Small Intestine	Alkaline	Enterokinase, activates trypsinogen into trypsin Erepsin, converts peptones into amino-acids Lipase, resolves fats into fatty acids and glycerol Invertase, converts cane sugar into glucose Maltase, converts malt sugar into glucose Lactase, converts milk sugar into glucose	

371. Absorption and Assimilation.--Only food in the form of a solution is capable of being absorbed Glucose, amino acids, fatty acids, glycerol and soluble soaps, the end-products of digestion, are the substances that are absorbable. Salts, alcohol, etc , are also absorbed without undergoing any change in the alimentary canal In absorption the food passes from the alimentary tract, through its lining membrane into the sub-lying blood- and lymph-capillaries Absorption takes place mostly in the ileum, but certain substances are absorbed from the stomach, e. g , water, iodides and alcohol

The inner lining of the ileum has a velvetty appearance due to the presence of a large number of minute finger-shaped processes called villi Each **villus** (Fig 111) consists of a small finger-like process of the submucous connective tissue continuous with the general submucosa of the alimentary wall, having blood-capillaries and lymph-capillaries **(lacteals)** in it, and covered by the ordinary lining epithelium of the ileum Villi are concerned with the absorption of the fats which have been split up into fatty acids and glycerol and then turned into soluble soaps All other kinds of absorbable foods are absorbed by the lining of the ileum. As soon as the soaps are absorbed by the villi, they are reconverted into fat-globules and the presence of these in the lacteals of the villi give their contents a milky appearance Note that the lacteals alone absorb the soaps, which therefore directly pass into the lymph-circulation, while the amino-acids and glucose are absorbed by the blood-capillaries, which therefore pass into the blood-circulation.

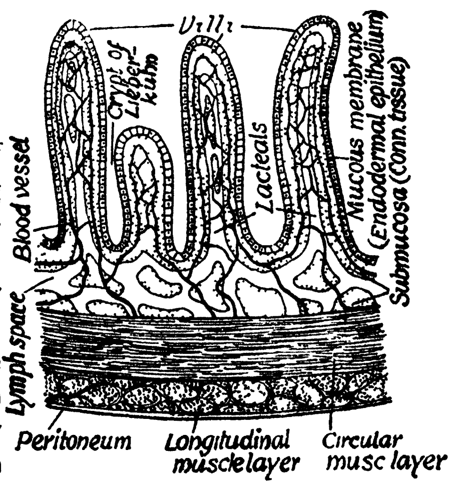

Fig 111, Three villi, in longitudinal section, as seen in a t s of portion of the intestinal wall, semidiagrammatic

The food that has passed into the vascular system still remains food, and unless it is built into protoplasm by the individual cells of the body aiding the growth and multiplication of the cells, it has not done its work. When food is built up by protoplasm into more protoplasm, it is said to be assimilated.

372. Defæcation.—The food of the rabbit contains a very large proportion of cellulose which is not acted upon by any of the digestive juices, but only by the bacteria abundant in the large intestine which convert it into soluble compounds and gases like hydrogen and methane (marsh gas) The soluble compounds and water are absorbed by the walls of the large intestine and the cæcum As more and more water is absorbed the contents of the large intestine become more and more solid and converted into the characteristic fæcal pellets The fæcal matter, consisting of the undigested food, excretory matter contained in the bile, insoluble soaps and products of bacterial decomposition, are expelled from the body. In man also putrefaction of the contents of the large intestine takes place by the action of bacteria before they leave the body.

REVISION QUESTIONS

303. Make a tabular statement of the various classes of food under the following headings Source, Chemical composition, Whether soluble or not, and Familiar examples

304 What do you consider to be a model diet ? Make out a menu suitable for your part of the country which contains all the necessary food principles and accessory factors

305 What is the value of water in food ?

306 What is the importance of the following in our dietary fresh fruits, green vegetables, milk, starch, meat, salts ?

307. Milk and eggs have been termed model foods. How do you justify the name ?

308 Proteins like white of egg are beneficial when eaten, but the same proteins when directly injected into the blood may act as poisons Account for this

309 How often does a fish—a frog—a python—a crocodile—a vulture—a rabbit—a cow—a tiger feed ? Which of these masticate their food and which not?

310 What are the functions of the liver ? What are the uses of bile ?

311 Which are the glands concerned with digestion ? Arrange them in the order of complexity of their structure

312 Define the terms digestion, absorption and assimilation

CHAPTER 34

MAMMALIA (Contd)—ORGANS OF RESPIRATION—BREATHING—ANALYSIS OF AIR IN HUMAN LUNGS—LARYNX—VOICE AND SPEECH

373. The Organs of Respiration.—In the general dissection of the rabbit we have already seen the organs concerned with respiration (Sect. 361) These organs differ in several respects from the corresponding organs of the frog In that animal the glottis opens into a laryngo-tracheal chamber and immediately after that into the lungs In the rabbit as well as in man, the portion represented by the chamber is drawn out into the long tube called trachea, with the larynx at the anterior end and the lungs at the posterior end. Thus there is a long air passage. Reptiles and birds also have a long trachea. In other words, a trachea is characteristic of all animals with a neck

The lungs themselves are not mere hollow sacs as in the frog, but highly spongy masses which expose a greater surface to the air and in which there are highly branching systems of air-tubes ending in a large number of small air sacs The larynx or voice box is well-developed in man, gifted with the power of speech, but in the rabbit in which voice counts for but little, it is not so well developed. The internal nares open not at the anterior end of the mouth as in the frog, but at the posterior, into the pharynx Neither the bucca cavity nor the skin performs a respiratory function Mammals can breathe either through the external nares or through the mouth

The most important difference, however, is in the respiratory mechanism Whereas in the frog, the air is *forced in* by the up and down movements of the floor of the buccal cavity, in mammals air is *sucked in* by the movements of the ribs and sternum and of the diaphragm.

The respiratory tract includes the olfactory passage with the external and internal nares, the pharynx, the glottis, the trachea, the bronchii and the lungs. The ribs with the intercostal muscles, the sternum and the diaphragm play an important part in the inspiration and expiration of air.

374. The Trachea.—This is a tube lying ventral to the oesophagus and made up of a series of C-shaped cartilgincus segments connected together by connective tissue The entire lining of this tube is ciliated The open portion of the C, also filled in by connective tissue, faces dorsalwards The cartilaginous rings strengthen the walls of the trachea and make it non-collapsible, but at the same time capable of bending, and yielding along the dorsal region to pressure from the oesophagus as the food-balls pass down into the stomach It divides at its hinder end into two bronchii, also having a similar structure The first two rings at the anterior end are enlarged and modified into the larynx or voice-box (Sect 381)

375. The Bronchii.—On entering the thorax the trachea divides into two bronchii These divide again, according to the number of lobes of the lung on each side Each of these divides again and again in the tissue of the lungs into **bronchioles,** minute air capillaries ending in dilated vesicles called **alveoli** or air-cells In the smallest tubes the cartilage-rings disappear The blood-capillaries of the lungs lie in the thin walls of these alveoli, making the exchange of gases possible

The entire air-passage from trachea to the smallest bronchioles is lined by a ciliated epithelium Ciliated cells also line the pharynx and portions of the nasal passage The cilia beat sharply and quickly in an anterior direction, causing the mucous secreted by the lining cells to be urged forwards into the pharynx, but regain their original position slowly so as not to disturb the onward flow of mucus Any particles that may reach the trachea or bronchial tubes by way of the inspired air will be caught in the mucus and sent out of the system into the oesophagus During an inflammation of the mucous membrane, for example, when there is a cold, the phlegm or mucus is passed into the larynx and expelled by coughing

376. The Lungs.—These are a pair of spongy bags In the rabbit the right lung consists of four lobes and the left of two lobes In man the right lung has three and the left two lobes They are placed in the thoracic cavity against whose walls they fit closely. Their shape is thus determined by the shape of the thoracic cavity. The lungs are covered by a double fold of cœlomic epithelium called the **pleura,** The outer layer or parietal pleura is closely adherent to the inner wall of the chest and the inner or visceral pleura closely invests the lung. The two layers are separated only by a thin layer of lymph which prevents friction of the one upon the other. The space enclosed between the two layers is an entirely closed one and is called the **pleural cavity.** The pleural cavities of the two lungs are also water-tight compartments, with no communication between them.

377. The Mechanism of Breathing.—In addition to the air tubes and blood-capillaries the tissue of the lungs contain elastic fibres which render them capable of contracting when inflated with air, just like a foot-ball bladder The air, however, enters the lung in a manner quite different from that of filling the bladder. The volume of the pleural cavity is increased by the expansion of the thoracic wall, and in order to fill the partial vacuum thus produced, the air rushes in through the nostrils or mouth and enters the lungs. This constitutes inspiration In expiration the thoracic wall contracts, enabling the elastic lungs to recoil and force the air out

378. Expansion of the Thoracic Cavity.—(Fig. 112) The pleural cavity is a closed chamber bounded by the thoracic wall—the vertebral column and muscles of the back dorsally, the ribs and intercostal muscles on the sides (Sect 361), the sternum and costal cartilages ventrally and the diaphragm posteriorly The ribs are movably articulated with the vertebra column Between the ribs are the external and internal intercostal muscles. The ribs are inclined backwards from their point of articulation with the vertebræ. When, therefore, the external intercostals contract the ribs move forwards, causing the sternum to move slightly ventralwards This results in the enlarging of the diameter of the thorax. By the contraction of the muscles of the diaphragm, the posterior wall of the thoracic cavity becomes less arched. This results

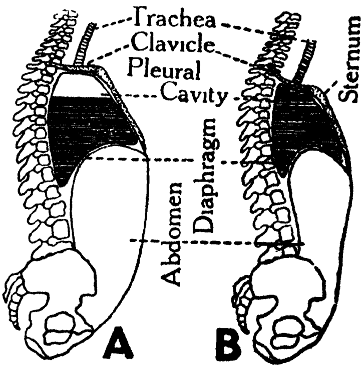

Fig 112 Side view of the human chest and abdomen A in inspiration; B, in expiration The unstripped area in A represents the increase in volume of the pleural cavity in inspiration

in the elongation of the axis of the thoracic cavity. As the thoracic cavity expands, a partial vacuum is created in the pleural cavity and causes the lungs to expand and take in air from the atmosphere to equalise the pressure.

379. Contraction of the Thoracic Cavity.—This is brought about by the pulling back of the ribs by the contraction of the internal intercostal muscles and the relaxation of the diaphragm, decreasing the diameter and the length of the thoracic cavity. As a result of this, the pleural cavity becomes smaller in volume, the lungs are allowed to recoil by their own elasticity and the air inside the lungs rushes out through the trachea.

380. The Air in the Lungs.—In ordinary respiration a man takes in and lets out about 500 c. c. of air with each inspiration and expiration. This constitutes what is known as the **tidal** air After expiration, however, about 2500 c. c are left behind in the lungs and this air is known as the **stationary** air In deep breathing, another 1500 c c or **supplemental** air could be inhaled, making the total capacity of the lungs of an adult person 4500 c c In deep expiration 3500 c. c. are expelled Of this 500 c c form the tidal and 1500 c. c. the supplemental, and the remaining 1500 is called the **complemental** air. The 1000 that is still left behind is called the **residual** air and cannot be expelled.

Analysis of Inspired and Expired Air.

	INSPIRED AIR	EXPIRED AIR	ALVEOLAR AIR
Oxygen	29·96	16 40	14 00
Nitrogen	79 00	79 50	80 50
Carbon dioxide	0 04	4·10	5·50
Temperature	*Variable*	33 9°C	37 5°C

In the alveoli of the lungs there is the least amount of oxygen and the greatest amount of carbon dioxide. This is as it should be, for, it is in the alveoli that the oxygen is exchanged for carbon dioxide. So also the temperature would be highest in the alveoli, because, in the other parts of the lungs the air is mixed with the tidal air

381. The Larynx.—(Fig. 113) The first two cartilages of the trachea are enlarged and form the voice-box or larynx. The more anterior one is called the **thyroid** and is a large plate of cartilage bent sharply on itself so as to form a V-shaped gutter the point of the V being ventral and constituting the prominence in the human neck known as Adam's apple. Like the rings of the trachea it is open dorsally, leaving a wide gap The second, viz, the **cricoid,** is smaller, but forms a complete ring, more developed dorsally and having the shape roughly of a signet ring. There is a membrane filling the gap between the thyroid and cricoid ventrally, immediately behind the Adam's apple, called the thyroid membrane This is of interest, as, in an emergency when an artificial opening for air becomes necessary it is this membrane that the surgeon pierces. On the anterior border of the dorsal side of the cricoid are the two **arytenoid** cartilages. it is to these that the dorsal ends of the vocal cords are attached, while the ventral ends are attached to the bottom of the gutter of the thyroid A small U shaped bone called the **hyoid** bone (homologous with the hyoid of the frog) is situated just anterior to the thyroid, the bend of the U being ventral, and forming the anterior limit of the entire vocal apparatus The **epiglottis** is a cartilaginous fold the posterior and narrower end of which is fastened to the thyroid. Its use is to close the larynx against entry of food or drink in the act of swallowing

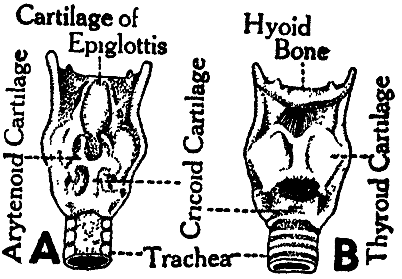

Fig 113 Human Larynx **A**, dorsal (back) and **B**, ventral (front) view

382. Voice.—The vocal cords are formed of white glistening bands of elastic tissue stretching dorso-ventrally as already indicated. In ordinary breathing they are moderately open, leaving a triangular space between, the base of the triangle being dorsal During the production of voice the cords come together, leaving only a narrow slit between The air that is expired throws the edges of the cord into vibration, producing sound The pitch varies with the degree of approximation of the cords to one another and with the state of their tension. The former is brought about by the rotation and approximation of the arytenoid cartilages by muscles, and the latter (tension) by rotation of the thyroid on the cricoid.

The male voice is deeper than the female voice, the difference being due to the larger size of the larynx and greater length of the cords in the male.

383. Speech.—Speech is the communication of ideas by articulate sound. It therefore involves not only the production of sound in the larynx, but also the modification of the sound by alterations in the shape of the mouth and pharynx by appropriate movements of the lips, teeth, tongue and palate This is known as articulation, without which speech is impossible. All mammals produce some sort of voice, but it is only the human species that can articulate it into speech. The musical notes of a bird are produced by mere variations in the pitch, but a parrot can be taught to imitate man in the articulation of sound

REVISION QUESTIONS

313. How does the mechanism of respiration of the rabbit differ from that of the frog?

314 What is the role of the intercostal muscles in the respiration of a mammal?

315 Why is it that it is more sanitary to breathe through the nostrils rather than through the mouth?

316 Can foreign 'bodies gain access into the wind-pipe of a mammal? If so, how are they got rid of?

317. In what respects does the respiration of a Vertebrate differ from that of an Insect?

318 What would happen if the thoracic wall were pierced up to the pleural cavity on one side—on both sides?

319. How is a cough—sighing—sneezing brought about?

320. How does inspired air differ from expired air?

321 Construct a working model of the respiratory mechanism with the help of a bell-jar, a foot-ball bladder, a sheet of India-rubber, some twine and a cork

322. Compare the larynx of man with the corresponding organ of the frog.

CHAPTER 35

MAMMALIA (Contd)—DISSECTION OF THE VASCULAR SYSTEM OF RABBIT —THE HEART—CIRCULATION—ARTERIES AND VEINS COMPARED—PORTAL CIRCULATION—BLOOD—CLOTTING OF BLOOD—WARM-BLOODED ANIMALS—VASCULAR SYSTEM OF FROG AND RABBIT COMPARED—HEART-BEAT—PULSE—REGULATION OF HEART —HUMAN LYMPHATIC SYSTEM

Material for Study A killed rabbit for each student or every two students, hearts of sheep or goats*

384. Dissection of the Systemic Blood-Vessels.—(Fig 114) Lay open the abdomen, thorax and neck of a rabbit, following the directions in Sect 359. Cut away the thoracic wall so as to expose the lungs and heart Note the **pericardium** and the **thymus,** an endocrine gland lying in front of the heart ventrally Open the pericardium and dip the dry handle of a scalpel into it, and note the **pericardial fluid** that sticks to it. Remove the pericardium as close as possible and pick away the fat that may be attached to the base of the heart, thereby exposing the large arteries and veins that leave or enter the heart Identify the right and left **ventricles** and **auricles,** and note the colour of the various parts What is the difference in colour between the right and left sides due to?

Practical work

Now proceed to make out the following blood vessels —

Veins. (1) The pair of **anterior vena cavæ** opening into the right auricle Each of these is a very short vein taking its origin from the union of (2) the **external jugular** lying along the ventral side of the neck, (3) the **sub-clavian** from the fore-limb and a small vein (4) the **internal jugular,** from the brain (5) The single **posterior vena cava** opens also into the right auricle. Trace it backwards down the thorax, through the diaphragm and on to the abdomen, and as you do so, note in order its tributaries, viz, (6) the **hepatic,** a short vein, from the liver, (7) right **dorso-lumbar,** (8) right **renal,** (9) the left **dorso-lumbar,** (10) the **left renal,** (11)the pair of **genitals,** (12) the pair of **ilio-lumbars,** (13) the pair of **external iliacs** or **femorals** and (14) the pair of **internal iliacs.**

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* Care should be taken to procure these with the roots of the aorta and pulmonary artery and the ends of the precaval, postcaval and pulmonary veins intact. Note that in the sheep or goat, as in man, there is only a common precaval opening into the right auricle, and not a pair as in the rabbit.

Arteries. It will be noted that several arteries run alongside veins, and it is convenient therefore to note them from the posterior end forwards —(1) the pair of **internal iliacs**, (2) the pair of **external iliacs (femorals),** (3) the pair of **common iliacs,** (4) the pair of **genitals,** (5) the two **renals** and (6) the two **dorso-lumbars** branch off from (7) the **dorsal aorta** and accompany the corresponding veins Other branches of the dorsal aorta, not thus accompanied, are: (8) the **posterior mesenteric,** (9) the **anterior mesenteric** and (10) the **cœliac** which supply the abdominal portion of the alimentary canal and the liver, spleen, pancreas, etc Note that these arteries pass between the folds of peritoneum which form the mesentery

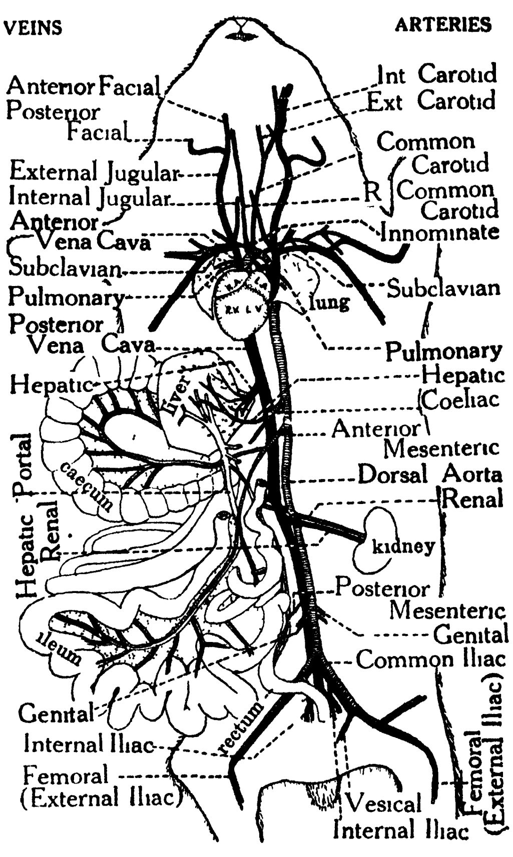

Fig 114. The main blood-vessels of the rabbit dissected from the ventral side Portal veins white; of the other vessels, those carrying deoxygenated blood, dark; oxygenated, striped

Trace the dorsal aorta round the left side of the œsophagus to its origin Immediately after leaving the heart it gives off (11) an **innominate** artery which divides into (12) the **right subclavian,** supplying the right fore-limb and (13) the **right common carotid,** running up the right side of the neck, (14) the **left common carotid,** and (15) the **left subclavian.** Note the asymmetry in the disposition of the arteries arising from (16) the **aortic arch** or bend of the aorta.

The **hepatic portal vein** runs in the mesentery and is formed by the union of several small veins coming from the stomach, spleen, duodenum, small intestine, colon, cæcum, and rectum. Trace the portal vein on to the liver, where it gives off a branch to each lobe.

(145) Sketch the ventral view of the heart, the veins and arteries and the portal vein

385. Dissection of the Pulmonary Blood Vessels.—Now cut the precaval and postcaval veins about an inch from the heart and the dorsal aorta at a point behind the heart Remove the heart with the lungs and pin them down, dorsal side up, on a dissecting board Locate and pin down the cut ends of the blood-vessels. Trace the **pulmonary arch** arising from the anterior border of the right ventricle. It immediately divides into the right and left **pulmonary arteries.** Trace them to the lungs. Note the **ductus arteriosus**[*], a short ligamentous cord, connecting the left pulmonary arch with the dorsal aorta.

Practical work

The **pulmonary veins** arise from the lungs On each side, the main vein is formed by the union of two smaller ones, and they open into the dorsal side of the left auricle by separate, but closely placed, openings.

(146) Sketch the dorsal view of the heart with the pulmonary arteries, ductus arteriosus, pulmonary veins, the roots of the aorta and the mouths of the veins

386. Dissection of the Heart.—(Fig 115) The heart of a goat or sheep may conveniently be substituted for that of the rabbit. Make out the roots of the several vessels Cut the ventricular portion about a third of its length from the apex. Wash the right and left ventricles clean of blood in running water. Make paper rolls about 5 inches in length Insert one roll into the (right) precaval vein and push it in till it issues at the cut end of the right ventricle. In the same way insert another roll into the left auricle through a pulmonary vein and push it in till it issues at the cut end of the left ventricle. Now pass a third roll in at the cut end of

Practical work

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[*] Also called ductus Botalli.

the right ventricle and make it issue out at the opening of the pulmonary arch, and a fourth one through the cut end of the left ventricle and out at the aorta.

(147) Sketch the transverse section of the ventricular region, noting the great thickness of the walls of the left ventricle compared with those of the right ventricle.

Note that the walls of the auricles are thinner than those of the ventricles. Open the auricles by cutting away a part of their ventral wall.* Wash out the clots of blood Between the auricles is the **interauricular septum,** a thin partition. From the right auricle, the roll of paper passes into the right ventricle through the **right auriculo-ventricular aperture,** a wide crescentic opening. Similarly the roll of paper from the left auricle passes into the left ventricle through the **left auriculo-ventricular aperture,** a large circular funnel-like opening. Cut open the right ventricle along its ventral wall following the oblique line marking the separation between the two ventricles on the surface of the heart. Near the right

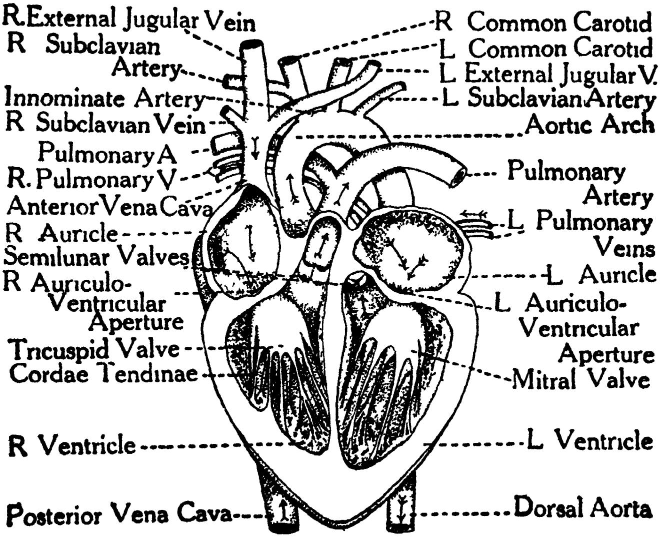

Fig 115 A dissection of the human heart from the ventral (front) side. The auricles, ventricles and the pulmonary trunk are exposed Arrows with single barbs show the course of deoxygenated blood, and with double barbs, of oxygenated blood.

auriculo-ventricular opening, continue the cut transversely so as to open the ventricular cavity fully. Pin down the ventricular wall. Take care not to injure the delicate valves in the ventricle. Note **the tricuspid valve** guarding the right auriculo ventricular passage, formed of three membranous flaps, whose free edges are projecting into the ventricle and connected by **cordæ tendinæ** to **papillary muscles** projecting on the inside of the ventricular wall. The **opening of the pulmonary artery** is towards the left, and is guarded by three pocket-like **semilunar valves,** the free edges of which are directed towards the artery. From the nature and arrangement of the valves, determine the direction of the blood in the right half of the heart.

Similarly open the left ventricle and pin down the ventricular wall to expose the cavity. Corresponding to the tricuspid valve in the right half is the **mitral valve,** guarding the **left auriculo-ventricular** passage, with only two flaps. Note the cordae tendinae and the **papillary muscles** as before. The **opening of the aorta** is towards the right and guarded by three **semilunar valves.** From the nature and arrangement of the valves determine the direction of the current of blood in the left half of the heart

The vascular system of man is similar to the rabbit's However, there is only a single anterior vena cava corresponding to the left anterior vena cava of the rabbit. It is called the superior vena cava,* which however receives the blood both from the right and the left sides of the head The two pulmonary veins from each lung open into the auricle independently.

(148) Sketch the dissection of the heart, indicating the direction of the current of blood by means of arrows.

387. The Heart of the Frog and Rabbit compared.—The dissection of the rabbit's (or goat's heart) reveals certain striking structural differences from the heart of the frog They are:—

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* Similarly, the posterior vena cava is called the inferior vena cava and the dorsal aorta is called the descending aorta, in human anatomy, in view of the fact that the antero-posterior axis of man is vertical

TABLE 13

THE HEARTS OF FROG AND MAMMAL COMPARED

HEART OF FROG	HEART OF MAMMAL
1 There are four regions, viz., sinus venosus, auricular region, ventricular region and truncus arteriosus	There are only two regions, viz., auricular region and ventricular region.
2 The ventricular region has but one cavity.	The ventricular region is divided into two, the right ventricle and the left ventricle
3. Accordingly there is only a single set of auriculo-ventricular valves.	Accordingly there are two independent sets of auriculo-ventricular valves
4 The outlet of the blood from the ventricle is single, viz , the truncus arterious.	There are two outlets, viz., the pulmonary orifice in the walls of the right ventricle, and the aortic orifice in the walls of the left ventricle

These structural modifications prevent any admixture of the oxygenated blood that is returned from the lungs to the left half of the heart and the deoxygenated blood that is returned from the systemic circulation into the right half of the heart, since that half is completely cut off from the left by the inter-auricular and the inter-ventricular septa

388. The Action of the Heart.—(Fig. 115) This is dependent on the power of contraction of the highly muscular wall of the heart resulting in the chambers of the heart becoming reduced in volume, thus tending to drive the contained blood out of them The two auricles contract simultaneously (auricular systole) and this is immediately followed by the simultaneous contraction of the ventricles (ventricular systole) Then follows a pause or diastole during which the auricles and ventricles are filling. The ventricular diastole persists during the auricular systole so that the blood forced out of the auricles can be received into the ventricles. The events taking place in the course of one complete beat together with the pause constitute a **cardiac cycle.**]

When the auricles contract the blood in them is prevented from escaping into the veins, because contraction begins at the base of the veins and close their openings into the auricles. The wave of contraction travels towards the ventricles, forcing the blood before it and sending it into the ventricles which are still in diastole. When the ventricular systole takes place, the blood is subjected to pressure, the capacity of the veins must be much larger than that of the arteries, as approximately as much blood must flow from the veins into the heart as is pumped out of it into the arteries with every beat.

In the larger veins, particularly of the limbs, there are paired or single valves (according to the diameter of the vein) so placed as to allow the blood to flow only towards the heart As the veins are mostly more superficially placed than the arteries, pressure variations of all kinds due to twisting or bending of the body or contact with external objects are easily transmitted into the veins, and the presence of valves in them prevent any flow of blood in the wrong direction, enabling only pressure in the right direction to have any effect.

In a dead rabbit, the arteries are practically empty, as the pumping action of the heart has stopped and the elasticity of their walls causes them to contract as much as possible. Hence the veins, with their highly distensible walls, are full of blood In a just chloroformed animal, however, the arteries will be full as the heart will still be functioning. (See also Sect. 31)

392. The Hepatic Portal Vein.—It will be noted that there is only the hepatic portal vein in the rabbit, as indeed in all mammals, the renal portal and the anterior abdominal (portal) present in the frog being both absent. The hepatic portal is formed mainly by the confluence of a large number of veins from the various parts of the alimentary canal (Sect. 384), and therefore, naturally carries the absorbed food away from it. Reaching the liver, the vein breaks up into a system of capillaries. Hence the sugars and amino-acids are distributed to the liver, where they are, so to say, arrested and retained The sugar is converted in the liver into a form of starch called animal-starch or **glycogen,** an insoluble substance Were this not so, there would be an excess of sugar in the blood immediately after feeding and digestion, and a lack of it at other times. This is prevented by the liver storing up the carbohydrate food and releasing it into the general circulation in regulated quantities after reconverting it into sugar.

The blood stream divested of the absorbed sugars it contained, now passes into the hepatic vein along with the blood from the hepatic artery and finally-joins the posterior vena cava on its way to the heart.

A portal vein, then, is one which, like other veins, begins in a capillary system, but unlike them also ends in a capillary system from which the blood has again to be collected before it can reach the heart. In other words, a portal vein is one which on its way to the heart is intercepted by some organ or other (the liver in the present case), in which it is broken up into capillaries. It can be compared to a river which loses itself in the sands of a desert only to reappear and find its way ultimately to the ocean.

393. Human Blood.—(Fig 117) Examine under the high power of the microscope a blood-film made as follows Sterilise a pin by heating it in a flame. Prick the end of your finger with it and squeeze out a tiny drop, the size of a pin-head. Touch the centre of two clean slides with the finger so as to transfer the blood on to them Applying the edge of one slide to the drop of blood on the other, draw it out into a thin smear, repeat for the other and allow the smears to dry.

Practical work

Make out the **red blood-corpuscles** (erythrocytes) found in large numbers all over the smear. Each will be seen to have a circular outline and a biconcave shape Red corpuscles are so small that 3200 of them can be laid flat on a line an inch long or more than ten millions in one sq inch They are made up of a stroma of protoplasm permeated with oxyhæmoglobin which is etimated to form 90% of the weight of a corpuscle No nucleus is discernible in them even after proper staining. They have a short life, probably two or three weeks, after which they are broken down in the liver, forming the bile-pigments On the other hand, they are being constantly formed by cell-division in the red bone-marrow.

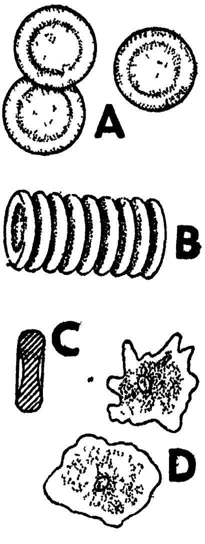


Fig. 117. Human blood corpuscles. **A**, three red corpuscles lying flat; **B**, a number of the same forming a rouleaux; **C**, a red corpuscle in section along its diameter; **D**, two white corpuscles with nuclei and pseudopodia.

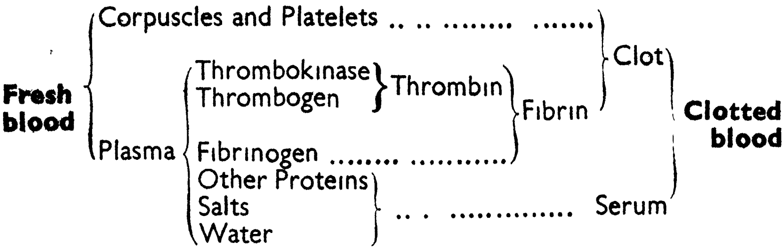
The **white corpuscles** (leucocytes) are slightly larger (1/2500 in.) and of irregular shape and much fewer in numbers, being only 1/500 times as numerous as the red. In addition, there are minute bodies called **platelets,** one-third the size of red corpuscles.

The **plasma**, a homogeneous fluid, pale yellow in colour and alkaline in reaction, is composed of (1) 90% water, (2) proteins, i. e., serum albumin, serum globulin, and fibrinogen, (3) carbohydrates, i e, a small trace of glucose, (4) fats in the form of soluble soaps, (5) salts of iron, calcium, potassium and sodium, such as chlorides, sulphates, phosphates and carbonates, (6) nitrogenous waste matter in the form of urea, (7) gases, viz, oxygen, carbon dioxide, and a trace of nitrogen, (8) hormones or internal secretions of the ductless glands, (9) anti-toxins which protect the body against disease and (10) enzymes like steapsin and perhaps maltase (See also Sects. 36—39.)

(149) Sketch the film of blood under the microscope

394. The Clotting of Blood.—When blood is shed from the blood-vessels, it sets into a jelly-like mass called the clot in from three to ten minutes This is nature's provision against excessive loss of blood as the clots forming in a wound would stop further hæmorrhage. If some fresh blood is drawn into a glass, it will form a clot. After a time the clot shrinks and a fluid called **serum** is expelled from it. On microscopic examination the clot is found to consist of the corpuscles of the blood enmeshed in a net-work of a thread-like substance called **fibrin.** The fibrin is formed from the dissolved fibrinogen (see above) of the plasma by the action of the enzyme **thrombin** which is stored as **thrombogen.** Now thrombogen can be activated into thrombin only by an enzyme **thrombokinase** which is stored in the walls of the blood-vessels. When a blood-vessel is cut the thrombokinase escapes into the blood and acting on the thrombogen forms thrombin Thrombin, in its turn, acts on the fibrinogen as mentioned above and converts it into fibrin But for this arrangement, it will be seen, that blood might clot even in the blood-vessels, which would be very detrimental to the animal As it is, the injury of the blood-vessel is the first of the series of steps that lead to the formation of a clot. In other words, a clot cannot be formed unless the blood-vessel is injured.

The changes undergone by the blood in passing from the fresh-drawn condition to the clotted one may be expressed as follows.



If fresh blood in a beaker is briskly stirred with a bunch of twigs, fibrin would form rapidly and be wound round the twig, leaving a red fluid, viz., defibrinated blood, in the beaker, which will not clot. Defibrinated blood consists of the corpuscles and platelets suspended in the serum

395. Aortic and Pulmonary Arches.—The absence of a partition into right and left in the ventricle of the frog entails, as we have seen (Sect. 34), the mixing of the oxygenated and deoxygenated bloods. In the mammals, on the other hand, the completion of the inter-ventricular partition prevents these two kinds of bloods from mixing. In order to ensure that the bloods do not mix in the arteries, separate outlets have to be provided for the oxygenated and deoxygenated bloods This is effected by splitting the arterial trunk (corresponding to the truncus arteriosus of the frog) into two distinct trunks, viz , the aorta arising from the left ventricle and the pulmonary arch arising from the right ventricle Indeed it can be said that, in the mammals, the partition of the heart has extended not only to the ventricular region, but also to the arterial trunk itself. Of the three pairs of arteries that are given off from the truncus arteriosus of the frog, we have in the mammals, the two carotids and the left systemic arising from the aorta and the two pulmonaries from the pulmonary arch The right systemic of the frog is suppressed in the mammal.

396. Vascular System of Frog and Rabbit compared.—The main modifications of the mammalian vascular system upon that of the amphibian type are:—(1) in the heart there is a complete separation between right and left halves; (2) there are two arterial trunks instead of one, allowing distinct outlets for the oxygenated and deoxygenated bloods from the heart; (3) there is no sinus venosus, the vena cavae opening directly into the right auricle; (4) the right systemic arch is absent, (5) a renal portal system is lacking, the iliac veins from the hind limbs uniting together to form the posterior vena cava; (6) of the two anterior vena cavæ only the right is present in man, while in the rabbit both persist, (7) the lymph-system (Sect. 402) possesses definite vessels with an endothelial lining and lymph-glands for the production of leucocytes, but lacks the lymph-hearts characteristic of the lower type; (8) blood-corpuscles are circular in outline and biconcave and devoid of nuclei and (9) the blood is warm.

397. Warm-blooded Animals.—Mammals and birds are spoken of as warm-blooded animals. That is, in health their temperature is kept at a constant level, i. e., they are **homoiothermous.** On the other hand, fishes, amphibians and reptiles are spoken of as cold-blooded To the human touch their bodies are always cold, and they do not have the ability to maintain a constant temperature. The temperature of their bodies varies with that of the surroundings Animals with a variable temperature are called **poikilothermous** (cf Sect 57).

The temperature of the human body is 98·4°F and that of the rabbit's 100°F, while in birds it is usually well over 100°F. It is slightly lower in the peripheral portions of the body. The temperature is maintained by a heat-regulating mechanism involving several organs of the body, particularly the skin and the nervous system (Sect 415).

In the warm-blooded animals, changes of temperature in the environment do not affect the temperature of the deeper parts of the body Day or night, summer or winter, sun or shade make no difference. On a cold day when radiation from the body would be greater, a larger amount of heat has to be produced than on a warm day. On the other hand, the fires of the body can be slowed down considerably on a warm day when the radiation is little.

398. Heart-Beat.—When listening to the heart-beat either by applying the ear to the chest of another person or by means of a stethoscope one can hear two distinct sounds for every beat of the heart followed by a pause. The first sound which is dull (*lub*) is said to be due to the rumbling caused by the contraction of the walls of the ventricles and by the vibration of the mitral and tricuspid valves. The second which is short and sharp *(dupp)* is produced by the sudden closure of the semilunar valves at the entrance of the great arteries.

The rate of heart-beat varies according to age. In very young children it is over 120 per minute, while in adults is is only 72 in normal health. It is generally quicker in women than in men and during work than when at rest.

Each beat of the heart sends a wave of expansion along the arteries. This wave is called **pulse** and can be felt on the surface of the body wherever arteries come close under the skin. Commonly the radial artery (lying over the radius near the wrist) is selected for this purpose. The rate of pulse might have been an accurate indication of the rate of heart-beat also, had it not been for the fact that some beats fail to appear on the wrist The average rate of pulse as well as of heart-beat in a normal, healthy adult is 72 per minute. In the early weeks of life it is from 120 to 140, decreasing with age. The pulse-rate is increased by several causes such as exercise, excitement, a full meal, various diseases, etc Rise in temperature of the body as in fever also produces a rise in the rate of heart beat and consequently of pulse Pulse travels along the arteries at a very great speed, only less than one-sixth of a second being required to reach the furthest artery in the body The flow of blood in the arteries, however, is very much slower

399. Blood-Pressure.--The contractions of the heart take place at regular intervals, and if one of the larger arteries is cut the blood will be seen to issue in jerks corresponding to the contractions of the ventricles From this one may be led to conclude that blood travels all through the body and back into the heart from the veins in intermittent streams corresponding to the beats of the heart This would have been the case had the blood-vessels not been elastic But we have seen that the arterial walls contain thick layers of elastic tissue (Sect 69 & 391) When the blood is forcibly pumped into the aorta, the capillaries offer a very great amount of resistance (known as **peripheral resistance)** to the free flow of blood through them owing to their very narrow diameter and consequent friction of blood against their walls. The result is that the elastic walls of the larger arteries are distended to receive the blood from the heart. In doing so their walls will be subjected to pressure of the heart transmitted to them through the blood itself, and the blood-vessels would exert an equal amount of pressure on the blood. This we call blood-pressure. When the arteries recoil in virtue of their elasticity, the blood is subjected to pressure and urged onwards, dilating the next portion of the artery and so on until in the smaller arteries the pressure is much reduced and in the capillaries it is less and in the veins least Hence, instead of flowing in jerks, the blood in the capillaries and veins flows in a steady and continuous stream unlike the blood that leaves the heart by way of the arteries

400 Control of Blood-Supply.—The amount of blood sent to the various parts of the body has to be varied from time to time For example, the stomach would require more blood during digestion and the muscles during activity than at other times If the diameter of the smaller arteries remained the same at all times such a regulated supply would not have been possible. As it is, the arteries are provided with circular muscle in its wall by the contraction of which their calibre can be regulated Normally they are in a state of partial contraction This we speak of as **arterial tone.** The tone can be increased or decreased by increasing or decreasing the intensity of the impulses which are continually reaching the muscles along the vaso-constrictor nerves (See Sect. 114), and the blood-supply is accordingly reduced or increased Thus it is possible to literally flush the organ concerned with blood during its active phases or to restrict its blood-supply to the minimum during periods of rest

401. Regulation of the Heart.—The heart is a self-acting or automatic organ and its normal muscular contractions are not induced by nerve-impulses as in the case of the ordinary muscles of the body. The heart, however, is supplied by branches from the vagus and the sympathetic nerves. The function of these is to regulate the frequency of the heart-beat. The vagus retards it while the sympathetic accelerates it Even after the heart is removed from the body, while still in a living condition, the contractions of the heart continue to take place in spite of the fact that the nerves of the heart have been severed.

402. The Lymphatic System of Man.—All mammals including man possess a well developed system of lymph-vessels, but owing to the fact that they are extremely thin-walled and the lymph is a colourless fluid, unlike blood, its dissection is not so easy as that of the blood-vessels. In essentials it resembles the lymph system of the frog (Sects. 41—45) ; but there are considerable differences between the two in the disposition of the main lymph vessels and in that in mammals they are welldefined vessels with a true endothelial lining, unlike the lymph-spaces or sinuses of the frog which are limited, not by a true endothelium, but merely by the surrounding organs and tissues. Besides, lymph-hearts are not present in the mammals

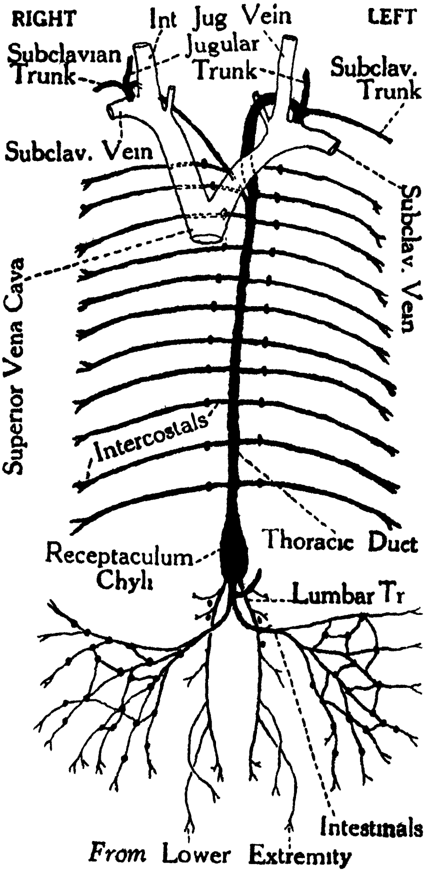


Fig 118 A diagram of the human lymphatic system, showing its main trunks from the ventral (front) side Lymph vessels dark, veins white Several lymph glands are shown in the intestinal net-work.

The main lymph-vessels (Fig. 118) are three, viz, the right and left lymphatic ducts and the thoracic duct. Of these the **thoracic duct** is the largest It begins near the right kidney and passes up the diaphragm and chest cavity alongside the aorta to the root of the neck, where it opens into the angle of junction of the left internal jugular and left subclavian veins. It receives the smaller lymphatics from the legs and the entire abdomen including the alimentary canal. The lymphatics from the alimentary canal open into its abdominal end which is specially enlarged to receive them. This enlarged portion is called the **receptaculum chyli,** because of the characteristic milky colour of its contents which are nothing other than the fats absorbed by the lacteals of the villi (Sect. 371).

The **right and left lymphatic ducts** drain respectively the right and left sides of the chest and head and the arms, in other words, all the parts of the body not draining into the thoracic duct. Each is formed by the union of a jugular and a subclavian trunk. On the right side, these meet near the subclavian vein, and open into the angle between the jugular and subclavian veins, reinforced by a small off-shoot from the upper end of the thoracic duct On the left side the arrangement is identical, excepting that the left duct opens into the venous system together with the thoracic duct.

The **lymph 'glands'** are well developed in mammals. They are solid bodies made of connective tissue and placed in the way of the lymphatics Leucocytes are formed in them by cell division and as the lymph flows past the glands, these are carried away into the lymph-circulation The glands being placed at close intervals, it follows that as the lymphatics approach the main ducts, the number of leucocytes become larger and larger. It will be noted that the lymph glands are not glands at all, but organs in which cells (leucocytes) are produced by active cell-division.

The flow of lymph is regulated by valves which allow it to go from the smaller to the larger vessels only These valves are placed at such short intervals that the lymphatics when full have a beaded appearance. Movements of the muscles, viscera, etc , pressing upon the delicate walls of the lymphatics, squeeze the lymph, which, owing to the presence of the valves, moves always only from the smaller to the larger vessels

REVISION QUESTIONS

323 Compare the heart of the rabbit with that of the frog Which of the two do you consider more efficient, and why?

324 How does a Mammal's blood differ from that of an Amphibian?

325. Double circulation is perfect in the rabbit, while it is imperfect in the frog Explain this statement

326 What method would you adopt to prevent excessive loss of blood from a wound? Why is it that blood inside blood-vessels does not clot?

327 Where and how are blood corpuscles formed?

328 What is the relation between the blood vascular system and the lymph vascular system? In what respects do the lymphatics of the mammal differ from those of the frog?

329. What is a ductus arteriosus? What is its homology?

330 Veins are placed more superficially than the arteries and are provided with valves What is the advantage of this combination of characters? How does the lymph flow, seeing that there are no lymph-hearts in the mammals?

331. Why are the walls of the left ventricle thicker than those of the right?

332. Why is the colour of blood scarlet, though the individual corpuscles are extremely light yellow?

CHAPTER 36

MAMMALIA (Contd)—DISSECTION OF URINOGENITAL ORGANS OF RABBIT—STRUCTURE OF KIDNEY—FUNCTION OF KIDNEY—URINE—FUNCTIONS OF LIVER—SKIN—CUTANEOUS GLANDS—HAIR—BODY-HEAT AND HOW IT IS KEPT CONSTANT—GLANDS—STRUCTURE OF GLANDS—THE DUCTLESS GLANDS

Material for Study A few killed rabbits, male and female, micro-slides of t s kidney of rabbit or rat, and v s human scalp

Practical work

403. Dissection of Male Urino-genital System.—(Fig 119, A). Open the abdomen of a male rabbit, locate the kidneys and remove the fatty tissue adhering to them Note the colour and shape of the kidney Each kidney is covered ventrally by the peritoneum, and therefore lies immediately ventral to the dorsal body-wall outside the coelom The notch on the inner side of the kidney is called the **hilus.** The ureter and blood-vessels enter or leave, as the case may be, this portion. Locate the **adrenal bodies** between the kidneys and the adjacent blood-vessels

Split one of the kidneys longitudinally, beginning at the outer side and ending at the hilus (See Fig. 120). Make out the following parts in the section (1) the renal **capsule** covering the entire kidney and made up of a tough layer of connective tissue, (2) the **cortex** forming the outer layer and containing the Malpighian bodies (which can be seen only in a microscopic preparation), (3) the **medulla**, the deeper part, radially striated on account of the uriniferous tubules, contained in it. These tubes open on the summit of little conical projections facing towards the hilus called (4) **pyramids.** Internally to the pyramids is (5) the **pelvis** or the expanded beginning of the ureter (6) The **ureter** is easily dissected by removing the peritoneum covering it and can be traced back to (7) the **urinary bladder,** a thin-walled muscular sac. The two ureters open into the bladder side by side

Slit up one of the scrotal sacs and expose the testis lying inside it Each (8) **testis** is an elongated ovoid body, about an inch and a half when fully developed.] Along its inner edge is a convoluted tube lying in a mass called (9) the **epididymis.** The epididymis is attached to the scrotal sac by a short cord called (10) the **gubernaculum.** Each epididymis is continued into (11) the **vas deferens,** a slender white tube passing forwards into the abdominal cavity through (12) the **inguinal canal.**

Press the other testis out of the scrotal sac and bring it forward through the inguinal canal into the abdomen

Each of the two vasa deferentia passes under the terminal portion of the corresponding ureter and the two run back to the neck of the bladder side by side.

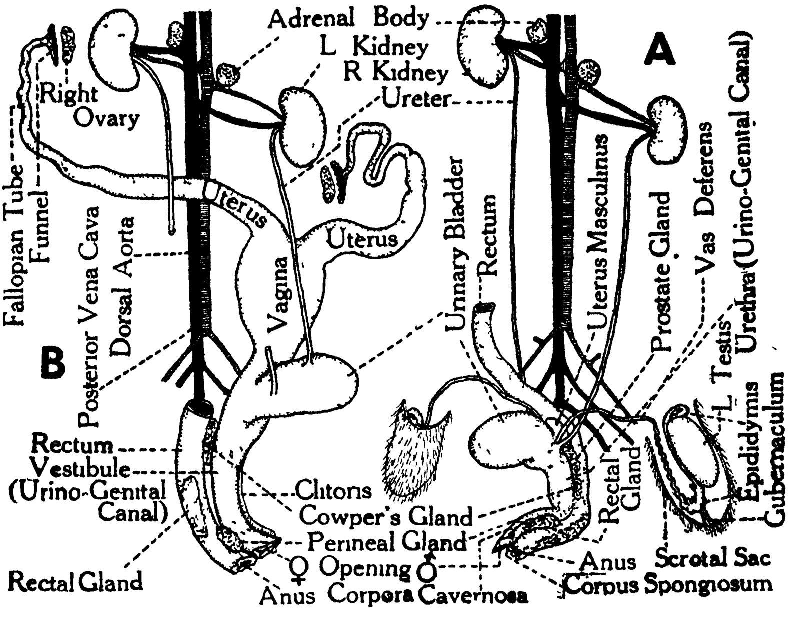


Fig 119 The urino-genital system of the rabbit, with the main blood-vessels and posterior end of the rectum **A**, male and **B**, female

Cut the pubic symphysis with a strong scalpel exactly in the median line and push the halves aside. Note (13) the **corpora cavernosa,** a pair of ligamentous bodies attached to the hinder border of the ischia. Cut them close to the bone Insert a blowpipe through the urino genital opening at the tip of the penis and inflate the bladder and urino-genital canal Ligature the penis near its end to prevent the escape of the air. Note the following:—(14)

the **urethra** or **urino-genital canal** into which the neck of the bladder is continued. Its terminal portion traverses a cord of vascular erectile tissue, called (15) **corpus spongiosum,** forming the dorsal portion of (16) the **penis,** while its ventral portion is formed by the pair of **corpora cavernosa.** The ends of the corpora cavernosa form (17) the **glans penis,** covered by a loose fold of skin called (18) the **prepuce.** (19) The **uterus masculinus** is a large median sac placed dorsal to the urethra and opening into it. The vasa deferentia open into 19. The urethra opens to the outside at the tip of the penis by (20) the **urino-genital opening.**

In addition to the parts seen above there are the following glands —(21) the **prostate gland** is a lobed structure placed on the dorsal and lateral sides of the uterus masculinus. (22) **Cowper's glands** are paired glands placed dorsal to the urethra and behind the prostates (23) The **perineal glands** are a pair of dark elongated bodies one on either side of the penis They open into the perineal pouches already noted (Sect. 355)

(150) Sketch the male urino-genital system

404. Dissection of the Female Urino-genital System.—(Fig 119, B) Open the abdomen of a female rabbit The kidneys and ureters are similar to those of the male Note however that the ureters open into the bladder more anteriorly than in the male Cut the pubic symphysis and inflate the bladder and urino genital passages as before. (24) The **ovaries** are a pair of pale yellow bodies lying behind the corresponding kidneys attached to the dorsal body-wall Each **oviduct** arises near the ovary, but not from it The first part of its length is narrow and convoluted and is called (25) the **Fallopian tube.** Its anterior end is widened into a funnel and lies alongside the ovary. Posteriorly it is continued into (26) the **uterus** often containing embryos. The uterus is wider than the Fallopian tube, but its diameter depends on the degree of development of the embryos within, as will be seen by comparing several pregnant females. The two uteri open independently into the next portion, viz., (27) the **vagina,** a wide median tube, posteriorly uniting with the urinary bladder to form (28) the **urethra (urino-genital canal** or **vestibule).** The urethra opens behind by (29) the **vulva** or urino-genital opening. In a position corresponding

Practical work

to the corpora cavernosa of the male is (30) the **clitoris.** Cowper's glands may be present, but are smaller. Perineal glands are similar to those of the male.

Between the two kidneys pass the aorta and the inferior vena cava. A renal artery starting from the aorta enters the hilus of each kidney and a renal vein leaves it to join the inferior vena cava The former supplies oxygenated blood to the kidneys, which after it is deprived of its nitrogenous waste matter is returned by the renal vein.

(151) Sketch the female urino-genital system.

405. Human Urinary Organs.—These are essentially like the rabbit's. The kidneys are placed in the dorsal region of the abdomen, in the loins, and covered by peritoneum. Each kidney is about 4 in. long and weighs over ¼ lb The right kidney is placed slightly lower than the left, whereas in the rabbit, the right is considerably in advance of the left. A section presents exactly the same structures seen in the rabbit. The urinary bladder is correspondingly large, measuring 5 in. in length, and placed in the pelvic cavity and its bottom is continued into the urethra

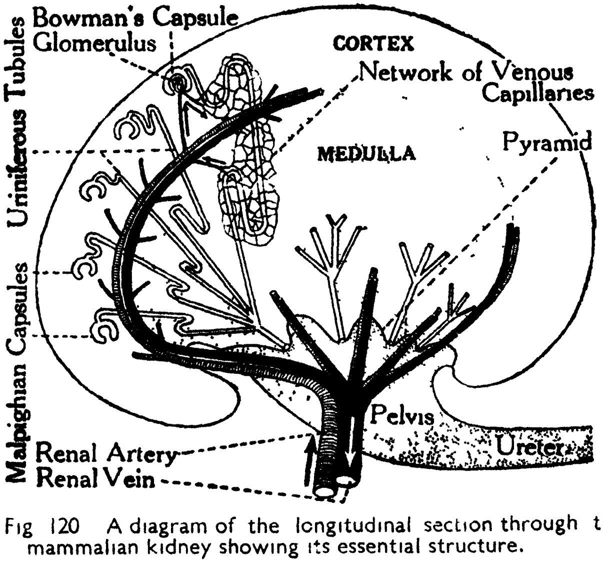


Fig 120 A diagram of the longitudinal section through the mammalian kidney showing its essential structure.

406. The Minute Structure of the Kidney.—(Fig 120) We have already seen that a section of the kidney reveals two distinct portions, the cortex and the medulla Examine a section of the kidney of the rabbit or the rat under the microscope. Note that the cortical portion contains a number of rounded structures, the **Malpighian capsules,** each consisting of a **Bowman's capsule** and a **glomerulus** as in the frog. Besides these the cortex shows the cut ends of a system of highly convoluted tubes (cf. Sect 48) These are the **uriniferous tubules,** which in the medulla are seen as straight tubes all converging towards the pyramids.

Practical work

Close examination of a number of serial sections will also show that the renal artery and vein lie between the cortex and the medulla, that the artery gives off branches into the cortical substance some of which enter the Bowman's capsules inside which they break up into the knot of capillaries called glomerulus, and that issuing from the glomerulus the vessel again breaks up into a net work of capillaries entwining the convoluted portion of the uriniferous tubules and finally joins the renal vein The straight portion of the uriniferous tubules may be considered to be their ducts which open on the pyramids into the pelvis of the kidney. Note that before opening into the pelvis several ducts may join together (furnishing an example of a compound tubular gland cf Fig 122, D).

(152) Sketch the section of the kidney under the microscope

407. The Function of the Urinary Organs.—The functions of the various parts of the Mammalian kidney are better known than those of the frog. Water and salts other than phosphates are removed by the thin lining membrane of the Bowman's capsules from the blood of the glomeruli, and urea and phosphates are drained off by the tubules from the net-work of capillaries surrounding them Since a large quantity of water is drained off in this manner both from the Bowman's capsules and from the uriniferous tubules, and this may tend to reduce the percentage of water in the blood, some of the cells of the tubules absorb the water from the lumen of the tubules and pass it back into the blood-capillaries. Thus the urine is concentrated. It now passes into the pelvis and thence to the ureter and trickles down drop by drop into the urinary bladder where it accumulates, the passage to the urethra being controlled by a sphincter. When the bladder is distended with urine the sphincter relaxes and the urine is forced out into the urethra and thence to the outside through the urino-genital opening in a continuous stream.

Closely related to this essential function of eliminating from the body the nitrogenous waste products in the form of urine is the function of adjusting the salt content of the blood and therefore of the osmotic pressure of salts in the blood, of eliminating abnormal products of metabolism, e. g, drugs absorbed by the intestinal wall and passed into the blood and toxins produced by bacterial action, of eliminating poisons of animal, vegetable or mineral origin that may get access into the blood, etc.

In short, the kidney is the organ which preserves the constancy of the composition of the blood.

408. Urine.—Urine is a clear liquid with a straw or a light amber colour, due to a pigment known as urochrome, faintly acid in reaction, but may be alkaline in the case of vegetarians Its specific gravity varies from 1 015 to 1 025 according to its concentration.

Every 100 parts of urine contain about 96 parts of water, and 4 parts of solids Of the latter, urea is the most important, constituting more than 2 parts, followed by common salt about 1 part. Small quantities of uric acid, creatin, creatinine, and various salts and pigments, accounting for the remaining one part

The quantity of urine excreted daily depends on various factors. Cold weather, taking of large quantities of liquids, a diabetic condition, etc, increase it, while hot weather, profuse sweating, feverish condition, etc decrease it

The course of urine is obvious It is formed in the Malpighian capsules and uriniferous tubules of the cortex, and passes down the straight tubes of the medulla into the pelvis of the ureter. Then it flows down the ureter into the urinary bladder and passes to the outside through the urethra at the urino genital opening

409. Functions of the Liver.—In Sect. 365 and 68, we have dealt with the gross and microscopic anatomy of the liver We have seen that one of its important functions is to secrete bile, a juice which is concerned with digestion, though it does not contain any enzyme. Bile is, however, as much an excretory product that has to be got rid of as it is a digestive fluid

Bile is a viscid fluid with a bitter taste and a greenish yellow colour, due to two pigments, bilirubin and biliverdin. These are reddish and green respectively, and the colour of bile varies according as the one or the other pigment predominates In addition to these pigments, bile contains mucin, cholesterol and certain salts Another function of the liver is to break down the effete red blood-corpuscles, and the bile pigments are derived from this source From about 15 to 35 ounces of bile are produced daily by the liver. In addition to aiding the pancreatic juice to emulsify and saponify fats, it stimulates the muscle fibres of the intestinal wall and so assists in moving its contents along It has also a slight antiseptic function

Liver cells extract harmful substances from the blood, and either convert them into harmless ones or expel them with the bile Liver cells also manufacture urea from the amino acids that are produced in the process of oxidation of the tissues and are passed into the of blood and lymph From the liver it is passed back into the blood and ultimately excreted by the kidneys

A very important function of the liver is what has been termed its glycogenic function The sugar abundantly present in the absorbed food naturally has to pass the liver, since it is collected first into the portal veins, which break up into capillaries in the liver The sugar is converted in the liver cells to animal-starch or glycogen and retained in them in the form of minute grains As the sugar in the blood is used up and more is required to meet the demands of the body, the glycogen is reconverted into sugar and passed out into the blood in regulated amounts Glycogen can be extracted from the liver by pounding up pieces of liver with sand and water

Lastly, the varied chemical activities of the liver involve a considerable amount of oxidation and consequently production of heat It thus contributes in no small measure to the warmth of the body

410. The Skin under the Microscope.—(Fig 121, A) Examine the section of the human scalp under the microscope and note that two distinct layers are seen, as in the frog, viz , the **epidermis** and dermis The epidermis is further divisible into two layers, the stratum corneum or horny layer forming the cuticle or scarf skin and the stratum Malpighi (Malpighian layer). The **stratum corneum** consists of hard horny cells in several layers, the outermost ones being flat and scale-like. These flat cells are continually being worn away On the soles and the palm of man the horny layer is nearly 1/20 of an inch, but much thinner on the rest of

Practical work

412. The Sebaceous Glands—(Figs 121, B & 122, F) These are alveolar glands associated with the hair and their secretion is a provision against the skin and hair becoming too dry The fatty substance secreted by the glands, called sebum, spreads over the skin and serves the purpose of a natural cream. Each gland consists of a few saccules communicating with a common duct which opens into the hair-follicles. The cells of the sebaceous glands are continuous with the Malpighian layer from which they take their origin. Each hair-follicle may be provided with more than one gland. The **mammary glands** are believed to be modified sebaceous glands.

413. Hair.—(Fig 121, B) This is as characteristic of mammals as the feather is of birds. Hairs afford protection from heat and cold There are a large number of air bubbles in the hair which make it a bad conductor of heat, hence the value of hair for making clothes The structure of the hair can be studied in a section of the skin. It will be seen that each hair has a **root** or bulb embedded in the skin and a **shaft** or stem projecting out from it The root is placed in a pit called the **hair-follicle** at the bottom of which is a papilla supplied with blood-vessels and nerves. The follicle is lined by cells of the Malpighian layer which also cover the papilla It is from the Malpighian cells of the papilla that the hair is produced. Whereas the dead cells derived from the Malpighian cells of the epidermis are rubbed off from the body as minute scales, the dead cells of the hair papillæ stick together and form hairs. The only living portion of a hair, therefore, is the papilla The hair grows by the addition at its proximal end of new dead cells from the Malpighian layer The shaft is dry and consists of only dead cells In a transverse section (Fig 121, C), the shaft is seen to be made of three parts. (1) a central **medulla** of round irregular cells, (2) a **fibrous layer** of closely packed cells and (3) an **external layer** of flat cells. The colour of the hair is due to the presence of pigment in the medulla. Each hair is provided with a **muscle** originating from under the Malpighian layer of the skin and inserted on the wall of the follicle in such a manner that the hair could be erected when the muscle fibres contract. The erection of the hair, known as 'standing on end', is a reflex action which is brought about by cold, fear, etc.

(153) Sketch the section of the human scalp under the microscope.

414. Body Heat.—Heat is produced in the body by the various chemical changes that are constantly going on in it. Chief among these is oxidation of the highly complex substance, protoplasm, resulting in simpler compounds like carbon dioxide, urea, water, etc, and producing a large amount of heat which is distributed to all parts of the body by the blood. The more important heat-producing organs are the muscles, the liver (a seat of various chemical actions) and the brain. Heat is produced all the time, but more actively when the organs concerned are functioning. Thus muscular activity increases the warmth of the body and induces perspiration

Heat is lost by radiation into the air, by conduction into objects with which we are in contact, by the evaporation of sweat on the surface of the skin, and in the breath, urine and fæces that leave the body. Five-sixths of the energy produced in the body by tissue-oxidation is lost in the form of heat and the remaining one sixth is utilised for work.

415. How Temperature is kept constant.—The skin with its sweat-glands and blood-vessels, and the nervous system play the most important part in the mechanism which maintains a constant temperature in the body The part played by the skin can be compared to that of the thermostat of a water-bath which automatically regulates the temperature of the bath and keeps it constant When the temperature of the body tends to increase either on account of work done by the body or on account of the high temperature of the atmosphere, the capillaries of the skin dilate and receive a larger amount of blood than usual The sweat glands are thus enabled to secrete more vigorously The increased perspiration results in an increased radiation from the skin and consequently the temperature, that might otherwise have risen, is kept normal. On the other hand, on a cold day or during inactivity, the cold causes a constriction of the skin-capillaries and blood is therefore made to remain in the deeper parts of the body. Consequently too much radiation is prevented. The activity of the sweat-glands would also be minimum, and there would be little evaporation from the surface of the skin However, in cold weather more heat is actually lost from the body than in hot, this loss being made good by increased production of heat For this a larger quantity of food is necessary. Hence, in the cold weather we have a better appetite.

The **adrenal bodies** are found adhering to the upper end of the kidney in man and other mammals. Their hormone, called adrenalin, helps to maintain blood-pressure and muscular tone. The latter effect is produced by regulating the supply of glucose given out by the liver into the blood, thereby supplying the muscles with the energy-producing carbohydrate food and counteracting fatigue. They exert a certain influence on normal sexual development also.

The **thyroid** consists of two oval bodies one on either side of the trachea below the larynx and joined by an isthmus Its hormone has been termed thyroxin and is very important for the normal growth of the young, both of body and mind. Removal of thyroids from a tadpole prevents metamorphosis, though the tadpole may continue to grow and become a large over size tadpole On the other hand when a tadpole is fed on thyroid gland, it forthwith metamorphoses into a tiny frog. Removal of the thyroid in children gives rise to a disease called cretenism, i e, deformed and underdeveloped body accompanied by idiocy and in adults to myxœdema (the symptoms of which are tremors, twitchings and slowness of mind and body). Iodine is present in thyroxin, and it is significant that diseases like cretenism which are due to improper functioning of the thyroid are commonly found in mountainous tracts remote from the sea, the source of iodine In Switzerland, one of such countries, the law requires table salt to be mixed with minute quantities of iodine to counteract the deficiency.

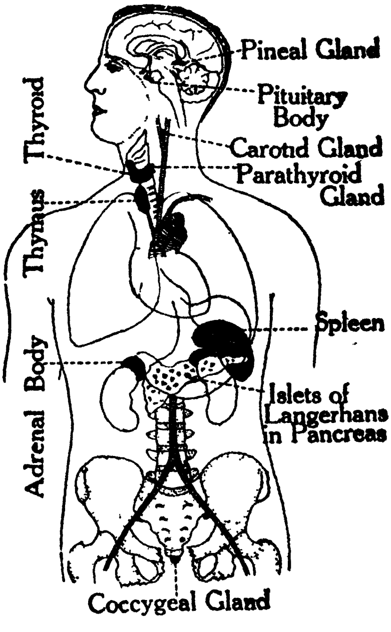


Fig 123 Diagram showing the positions of chief ductless glands of man. The glands are shaded dark

The **parathyroids** are two small glands situated on the border of the thyroids or actually embedded in its tissue Their hormone regulates calcium metabolism Removal of the glands reduces the calcium content of blood to such an extent as to cause severe cramps (tetanus) in a very short time, ending fatally

The **pituitary body,** the most dominant of them all, is a small gland placed under the infundibulum inside the skull Its secretion has been called pituitrin The glands consists of two lobes. The anterior lobe regulates growth, controls the development of sexual characters and stimulates the secretion of milk The posterior lobe regulates the flow of urine, the contraction of the uterus in child-birth and to a certain extent blood-pressure

The **thymus** is well developed and functional in the young, but atrophies in the adult. It is placed in the mediastinum at the base of the trachea. Its function is to control the rate of development of sex organs

The pancreas contains two kinds of glandular units, the pancreatic lobes proper which secrete the pancreatic juice, and the **islets of Langerhans,** isolated glandular units scattered all over the pancreas and concerned with the secretion of insulin, their specific hormone Insulin regulates the carbohydrate metabolism of the body. It enables tissues to take up glucose from the blood and oxidise it Lack of insulin in the blood prevents the tissues from utilising glucose, and causes it to be excreted with the urine. This condition is known as diabetes mellitus, for which the present day treatment is to inject small dozes of insulin

The gonads, testes and ovaries, contain what are called **interstitial cells** in between the seminiferous tubules or in addition to the primordial ova, as the case may be These secrete hormones which are resorbed into the blood, and play an important part in regulating sexual activity and the development of secondary sexual characters. Removal of the testes leads to non-development of male sexual characters in the young and in the adult to a return to an infantile condition as far as sex is concerned. If a bit of the ovary from a female animal is grafted on to the peritoneum of a young castrated male, it begins, in course of time, to show certain female characters.

REVISION QUESTIONS

333. Trace the course of urine from the uriniferous tubules to the outside.

334. What are the factors that determine the quantity of urine excreted in a given period of time?

335. Compare the kidney of a rabbit with that of a frog

336. What are the various kinds of tissues met with in a section of the kidney?

337. Where is urea produced? Is any urea produced in the kidneys themselves?

338. Which is the element that almost entirely leaves the body in the urine? In what form is it taken into the body, in what form is it found in the body and in what form does it leave the body?

339 What are the waste products other than urine of the Vertebrate animal? How do they leave the body?

340. What are uterus masculinus and clitoris? What are the structures homologous to them in the opposite sex?

341 What is the position of the kidneys and ureters in relation to the abdominal coelom? What is the morphology of the cavity of the scrotal sac?

342 What is the advantage, if any, of having a separate opening for the urino-genital system as distinct from the anus?

343. What is the difference between secretion and excretion?

344 Compare the structure of the skin of the frog with that of a mammal

345. What are the mammalian characters met with in this chapter?

346 What is the use of hair to the mammal? What are the animals whose hair is useful for manufacture of woollen cloth? Why is it that all mammals are not of economic importance in this respect?

347 There is not sufficient hair on the body of man to form a natural clothing for the body The whale has practically no hair. Explain these

348. Describe how the temperature of the mammalian body is kept constant? What is the advantage of the homoiothermous condition over the poikilothermous?

349. Which are the glands of the body that have both an ordinary function and an endocrine function? Which are the glands that are purely endocrine? Which organs perform an endocrine function in addition to their ordinary (non-glandular) function? Mention the ductless glands which have more than one hormone.

CHAPTER 37

MAMMALIA (Contd)—THE SKELETON OF RABBIT AND MAN COMPARED WITH THAT OF THE FROG.

Material for Study An articulated and mounted skeleton of the rabbit; a few sets of complete disarticulated skeletons of the rabbit; a human skeleton, a human skull in longitudinal section

If possible, students should prepare for themselves the skeleton of the rabbit, following the directions in Sect 70.

418. Skull of Rabbit.—(Fig 124) As in the frog, the skull consists of the cranium which lodges the brain, the olfactory capsules and the auditory capsules. The upper jaw in the mammal is more closely associated with the skull than even in the frog. The sockets of the eyes are not open at their bottom. The vomer and the sphenoid, which in the frog were readily visible on the ventral side, are now covered in by the **palate,** with the result that the internal nares open behind it. The cranium is proportionately larger than that of the frog. The skull is almost entirely bony. Finally, the facet for the articulation of the lower jaw is shifted forwards, while in the frog it is right at the back end of the jaw-arch. The lower jaw consists of a single bone, viz., the dentary.

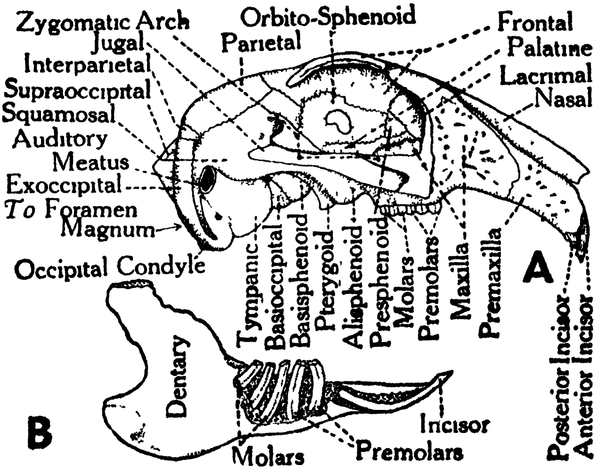


Fig 124 **A**, right side view of the skull of rabbit, **B**, the right ramus of the lower jaw, with the roots of the teeth exposed.

419. Human Skull.—(Fig 125) The human skull shows several peculiarities. The cranium proper or brain case is proportionately very large. The interparietal is absent, maxilla and premaxilla are fused into a single upper jaw bone on each side The two frontals are fused into one large plate. There is only a single occipital formed by fusion of all the four occipitals. All the sphenoid bones are fused

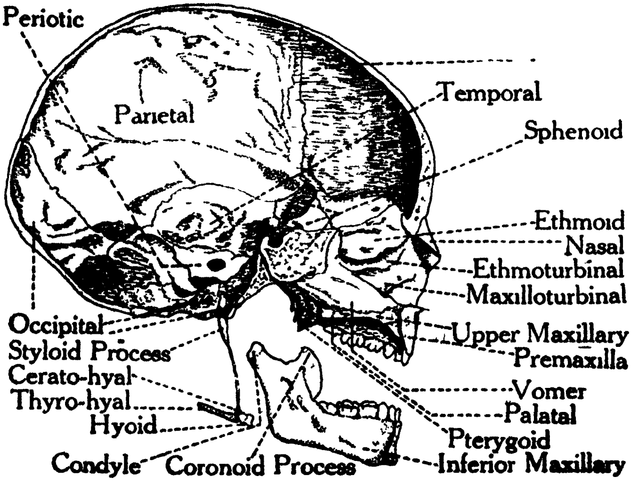


Fig 125 Sagittal section of the skull of a child of six together with the left ramus of the lower jaw

into a single bone. The periotic and tympanic fuse with the squamosal and give rise to a single bone called temporal As a result of the posterior bulging of the brain case the foramen magnum comes to be placed further forwards towards the middle of the base of the skull. The jaws are much fore-shortened The lower jaw forms a single bone by the symphysis of the two rami

(154) Sketch the dorsal and ventral views of the skull of the rabbit and with the help of the following table indentify and label the bones.

(155) Repeat for the human skull and compare it with the rabbit's.

(156) Sketch the side view of the lower jaw of the rabbit, together with the teeth.

(157) Repeat for man.

TABLE 14

420. BONES OF THE SKULL, JAWS AND HYOID OF RABBIT AND MAN

(Italics mean Investing bones Paired bones in plural)

RABBIT Brief Description	REGION – NAME OF BONE	MAN Brief Description	CORRESPONDING BONES IN FROG
	Cranium		
Large, roofing behind	*Parietals*	Large, flat bones of roof and sides	Fronto-parietal
Wedged between parietals behind	*Interparietal*	Absent	
Roofing, in front	*Frontals*	Forehead, halves fused into a single flat bone	
Upper edge of foramen magnum	Supraoccipital	A single bone round foramen magnum formed by fusion of all four, called occipital, carries occipital condyles	Exoccipitals
Sides of foramen magnum, carry occipital condyles	Exoccipitals		
Lower edge of foramen magnum and floor of cranium behind	Basioccipital		
Floor, in front of basioccipital	Basisphenoid	A single bone called sphenoid, formed by the fusion of all six Lies in the floor of the cranium between squamosals, shaped like a bat on its wings	Cartilaginous floor of cranium
Floor, in front of basisphenoid	Presphenoid		
On each side of basisphenoid	Alisphenoids		
On each side of presphenoid, perforated by optic nerves	Orbitosphenoids		
Median, forms nasal septum	Mesethmoid (Ethmoid in Man)	Between orbits, forms roof of nose	Sphenethmoid
	Nasal Capsule		
Roof of nasal cavity	*Nasals*	Bridge of nose	Nasals
In front of presphenoid, slender, below nasal septum	*Vomer*	Hinder and lower part of nasal septum, separates nasal cavities	Vomers
Three pairs of scrolls of thin bone projecting into nasal cavity and arising from maxillæ (anterior), ethmoid (posterior) and nasal (dorsal)	Ethmo-turbinals Maxillo-turbinals Naso-turbinals	Two pairs of scrolls of thin bone arising from ethmoid called Superior and Middle Turbinals, and one pair from maxillæ called Inferior Turbinals None from Nasal	✓ 442
	Auditory Capsules		
On outer side of basioccipital	Periotics	Both fused with temporals on each side	Prootics plus cartilage
Flask-like enclose tympanic cavity and ear-pit	Tympanics		

	Auditory Ossicles		
Chain of three small bones in tympanic cavity of each side	Stapes Incus Malleus	Chain of three small bones in tympanic cavity of each side	Columellæ Quadrates Hind end of Meckel's cartilage
	Orbit		
In anterior wall of orbit, between frontal and maxilla	*Lacrimals*	On nasal side of orbit	
	Upper Jaw		
Anterior, lodge incisors	*Premaxillæ*	Fused on each side to form Superior Maxillary, lodge teeth and form anterior three-fourths of palate	Premaxillæ
Carry remaining teeth, form anterior part of palate and anterior end of zygomatic arch	*Maxillæ*		Maxillæ
Greater part of zygomatic arch, between maxilla and squamosal	*Jugals*—*Malars*	Cheek-bone with process forming anterior half of zygomatic arch	Quadrato-jugals
Side and floor of nasal passage behind, hinder half of palate	Palatines—Palatals	Posterior one-fourth of palate	Palatines
Small, below basi- and ali-sphenoids	Pterygoids	Fused with sphenoid, behind palatals	Pterygoids
Below parietal, a process extending to zygomatic arch, carry facets for lower jaw	*Squamosals*—*Temporals* (in man)	Temple-bone, produced into hinder end of zygomatic arch, carries facet for lower jaw	Squamosals
	Lower Jaw		
Carry lower teeth, meet in symphysis in front	Dentaries (Inferior Maxillaries in man)	Carry lower teeth, strongly fused at symphysis	Dentaries
	Hyoid Apparatus		
Stout transverse bone at base of tongue	Hyoid	Transverse U-shaped bone at base of tongue	Body of Hyoid
Short Cerato-hyal	Anterior Cornua	Short Cerato-hyal	Lower ends of Anterior Cornua
Longer Thyro-hyal	Posterior Cornua	Longer Thyro-hyals	Posterior Cornua
Projecting bone attached to periotic region	Styloid Process	Projecting bone attached to periotic region	Upper ends of Anterior Cornua

Note that the entire skull is formed of bone and there is no cartilage as in the frog. The **orbit** of the eye in man is bounded by a number of bones: sphenoid and frontal in the roof, ethmoid, superior maxillary, sphenoid and and lacrimal forming the inner wall, malar and sphenoid forming the outer wall, and superior maxillary, malar and palatal forming the floor Note also the sutures especially between the flat bones of the cranium, which are dove-tailed.

421. Vertebral Column of the Rabbit.—Examine the skeletons before you and note the five groups of vertebræ, viz, **cervical** or the seven neck-vertebræ, the **thoracic** or the twelve (sometimes thirteen) chest-vertebræ carrying ribs, the **lumbar** or the seven (sometimes six) back-vertebræ usually, the **sacral** vertebræ forming a fused mass consisting of three or more vertebræ, to the first of which the pelvic girdle is attached, and the **caudal** vertebræ, or tail-vertebræ about sixteen in number

Examine a typical vertebra, e g, the second lumbar vertebra (Fig. 126, D) more closely. Note the body or centrum, the neural arch, a pair of transverse processes, the pre-zygapophyses and the post-zygapophyses. (Compare with the 3rd vertebræ of the frog, Sect 75). Note the following points in which it differs from the frog's. (1) The ends of the centrum are flat while in the frog the anterior end is concave and the posterior convex. (2) Either end of the vertebra is covered by a thin plate of bone, the **epiphysis,**

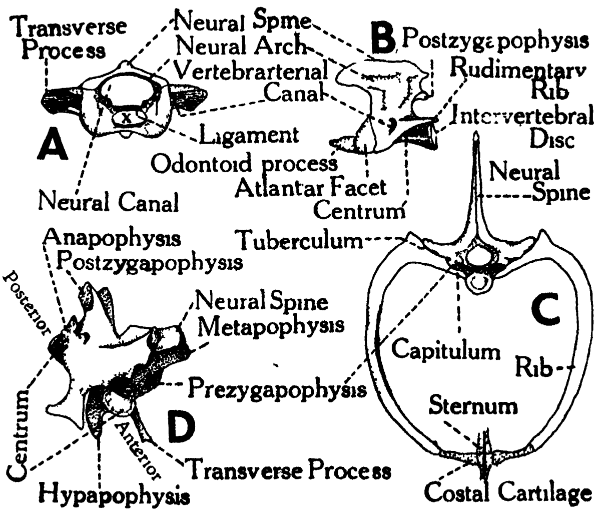


Fig 126 Vertebræ of the rabbit **A**, the atlas, anterior view, x marking the socket for the odontoid process, **B**, the axis seen from the left side, **C**, third thoracic vertebræ with ribs and sternum, front view; **D**, second lumbar vertebra, antero-lateral view from right

with which it fuses after the animal becomes full grown. (3) A median ventral process called the **hypapophysis** projects from the centrum downwards and forwards. (4) Projecting forwards and outwards over the pre-zygapophyses are a pair of stout processes, the **metapophyses.** (5) Similarly projecting backwards below the post-zygapophyses are the pair of **anapophyses.**

Examine the vertebræ of each region closely to see in which of the vertebræ the three last mentioned processes are found and in which not.

(158) Sketch the side and anterior views of the second lumbar.

422. Peculiarities of other Vertebræ.—The **cervical** vertebræ have short ribs fused with them to form the perforated transverse processes Through these perforations, called the **vertebrarterial canals,** on each side runs the vertebral artery. The neural spines are short The first cervical or **atlas** (Fig 126, A) is ring-like with broad transverse processes The neural canal is large and below it is a space (marked x) separated from it by a transverse ligament Into this space fits the odontoid process of the second vertebra, which therefore forms a pivot on which the atlas together with the head can turn On the other hand, the head can rock on the atlas into whose anterior facets the occipital condyles of the skull fit. These facets are termed the condylar facets.

The second cervical or **axis** (Fig. 126, B) has a broad flat centrum produced forwards like a tooth called the **odontoid process** fitting into its socket in the atlas The anterior articular surfaces for the atlas, the atlantar facets, are large and convex Pre-zygapophyses are absent Why?

The **thoracic** vertebræ (Fig. 126, C) are marked by mostly long backwardly directed neural spines The centra are short and thick from above downwards. The ribs are attached to the thoracic vertebræ, in two places, viz., to the side of the centrum and to the under surface of the short stout transverse processes In the hinder region, the thoracic vertebræ gradually become larger and larger, bear neural spines of diminishing size and metapophyses begin to appear on the ninth thoracic, and are of increasing size backwards. In other words the posterior thoracics gradually merge into the anterior lumbars in most respects, The **lumbar** vertebrae are of large size. The anteriormost one may sometimes bear a thirteenth pair of ribs The transverse processes are large, increasing in size backwards Hypapophyses are borne by the first two The neural spines are directed forwards.

The **sacral** vertebrae consisting of a variable number of vertebrae fused with each other form the **sacrum.** The usual number is three or four. Of these the first one or two are articulated to the pelvis by their strong expanded transverse processes (with the rudiments of the ribs) The first sacral is the largest, and the hinder one smallest, gradually passing into the caudal.

The **caudal** vertebrae gradually decrease in size backwards, until the last few are reduced to mere rod-like centra without any of the other parts.

Between the centra of the vertebrae, in the unmacerated skeleton there are **intervertebral discs** made of elastic fibro-cartilage which allows of the bending of the entire vertebral column.

(159) Sketch the anterior view of the atlas, side view of the axis, posterior view of one of the last cervicals and hind view of a thoracic.

423. The Human Vertebral Column.—Examine the human vertebral column and note the following important differences — There are only 5 lumbar vertebræ, while the sacrum consists of a fused mass of 5 vertebræ There are no free caudal vertebræ, which are represented by the **coccyx,** made of four coccygeal vertebræ, homologus to the caudal of the other mammals. The metapophyses, anapophyses and hypapophysis noticed in the lumbar vertebræ of the rabbit are absent

424. The Ribs and Sternum—There are twelve pairs of ribs according to the number of thoracic vertebrae They are curved bony rods movably articulated with the thoracic vertebrae by the dorsal, and with the sternum by the ventral ends Examine a typical rib from the middle region of the thorax of man. The head of the rib or **capitulum** (Fig 126, C) articulates with a concave surface—between two centra, viz., the one corresponding to the rib and the one immediately anterior to it. A little distance from the capitulum on the dorsal side of the rib is the **tuberculum,** a small raised portion which articulates with the transverse process of the corresponding vertebra.

In the rabbit, the first seven pairs of ribs articulate directly with the sternum by their own **costal cartilages,** that is, their ventral cartilaginous ends, and are termed true ribs The 8th and 9th do so indirectly through the costal cartilages of the 7th and are termed false ribs. The last three pairs do not reach the sternum and are called the floating ribs. The sternum is a laterally compressed rod of bone having six metameric **sternibrae,** of which the anterior and largest is the manubrium The last segment is very long and is called the xiphisternum

In man, the arrangement is slightly different There are three pairs of false ribs, viz., the 8th, 9th and 10th, while the last two are floating. The sternum is not laterally compressed, but dorso-ventrally depressed, and its metamerism is more marked.

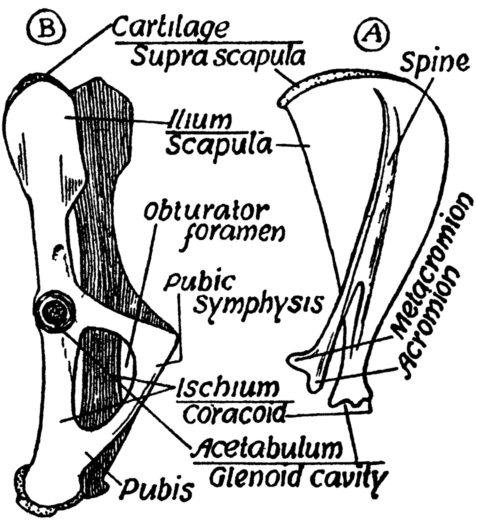


Fig 127 The limb girdles of the rabbit from the right side **A**, pectoral and **B**, pelvic girdle

(160) Sketch a thoracic vertebra with its ribs from the anterior view.

425. The Appendicular Skeleton. — (Figs 127 & 128) The terrestrial vertebrates have, with few exceptions, the same general plan of limb-structure which we have already seen in the frog, often referred to as pentadactyle The arrangements in the rabbit and man not only fall into line with that of the vertebrates in general, but are so similar in all essential respects, that it will be convenient for us to make a comparative study of the frog, rabbit and man with the help of the table below. Articulated, and disarticulated limb skeletons of the frog, rabbit and man should be examined side by side.

TABLE 15

426. APPENDICULAR SKELETON OF FROG, RABBIT AND MAN

PART	FROG	MAN AND RABBIT
Pectoral Girdle	Halves fused ventrally by epicoracoid	Halves distinct and widely separated. In man they meet the sternum through the clavicles
Suprascapula	Broad plate of cartilage	Narrow ridge of cartilage attached to dorsal end of scapula.
Scapula	Normally developed	Very flat triangular bone with glenoid at ventral end A prominent **spine** runs down the plate and ends in a free process called **acromion.** In rabbit a **metacromion** arises from the posterior border of the acromion The anterior border is continued below as the coracoid process
Coracoid	Well developed	Represented only by **coracoid process** of scapula
Procoracoid cartilage	Persistent, but clavicle develops as a covering bone	Replaced by the clavicle In the rabbit very small, connected to sternum and scapula by ligaments In man well developed and extending between scapula and sternum
Pelvic Girdle	Symphysis formed by all three elements.	Symphysis formed only by pubis In man the three elements fuse in adult life to form a single bone called **os innominatum** on each side
Ilium	Long, articulates with 9th vertebra by anterior end	Broad, flat, articulates with first or first and second sacrals by inner sides In man, ilia are pushed aside and form the sides of the pelvic basin
Ischium	Small bone at the hind end No obturator fenestra	Flattened postero-dorsal region Separated from pubis by **obturator fenestra**
Pubis	Ventral, cartilage	Ventral, smallest bone, forms the symphysis
Fore-Limb		
Humerus (Upper arm)	Short thick, with strong deltoid ridge	Long, with deep olecranon fossa for articulation with olecranon process of ulna
Radius, Ulna (Forearm)	Radio-ulna.	Radius along the side of the thumb or inner (first) digit. Ulna along the side of the small finger or outer (fifth) digit, with **olecranon process** at proximal end
Carpus (Wrist)	Six carpals in two rows	Nine carpals, proximal row of three, viz,, **radiale, intermedium** and **ulnare,** a central bone called **centrale,** and distal row of five corresponding to the five digits and called **distalia,** 1, 2, 3, 4 and 5 respectively, numbers 4 and 5 being fused into one (Fig. 128, A)
Metacarpus (Hand)	Five metacarpals, first rudimentary.	Five metacarpals. First very small in rabbit, short in man.
Phalanges (Fingers)	0. 2. 2 3 3. No claws	2 3. 3. 3 3. Terminal phalanges bear claws in rabbit, nails in man.

Hind-Limb		
Femur (Thigh)	Long, thin, with two bends.	With well developed trochanters or ridges
Tibia, Fibula (Leg)	Tibio-fibula.	Tibia larger than fibula, the two being fused distally in rabbit, free in man
Tarsus (Ankle)	Four tarsals in two rows	Six tarsals in rabbit, seven in man, in three rows
	Proximal row, astragalus and calcaneum.	Proximal row, **tibiale** and **intermedium** fused (astragalus) and **fibulare** (calcaneum) Central called **centrale.**
	Distal row of two cartilages.	**Distalia,** three distinct bones in rabbit, viz , 2, 3, and 4 and 5 fused No I is fused with metatarsal of innermost digit Four in man, viz , 1, 2, 3 and 4 and 5 fused
Metatarsus (Instep)	Five metatarsals and calcar	Metatarsal No I absent in rabbit, all five present in man
Phalanges (Toes)	2 2 3 4 3	0 3 3 3 3 , terminals clawed in rabbit In man, 2 3 3. 3 3 , terminals nailed

Note —The terms *radiale, ulnare, tibiale* and *fibulare* are derived from *radius, ulna, tibia* and *fibula* at the distal extremities of which they are respectively placed

The **patella** is a small bone, familiarly known as the knee cap, present in both rabbit and man. It is an ossification in the tendon of a muscle where it runs over the knee. Such bones, which are neither cartilage bones nor membrane bones, are called *sesamoid* bones.

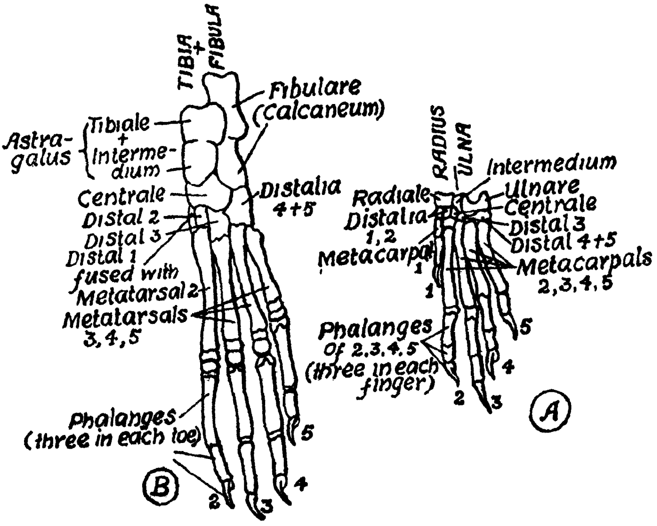


Fig 128 Skeleton of the hand and foot of the rabbit **A**, back of the left hand and **B**, back of the left foot

427. The Human Hand.—Note the movements which the human limbs are capable of. The shoulder and hip-girdles allow of a wide range, while the elbow and knee are hinge-joints in which movement is confined practically to a single plane. In turning the palm upside down, note that the radius is crossed over the ulna so that the thumb moves through 180° while the ulna retains its position. This attitude is called *pronation*, while the normal attitude, when the palm is facing upwards and the ulna and radius are parallel, is known as *supination*. This peculiarity is of very great interest in that very many of the complex movements of the forearm are dependent upon the ability to pronate and supinate.

The great agility and ability to act together or independently of the fingers make it possible for man to perform the most complex and delicate movements which have helped him very much along the path of his progress

(161) Sketch the anterior view of a thoracic vertebra with its ribs and the sternum, side views of the pectoral and pelvic girdle and the skeleton of the fore- and hind-limbs of the Rabbit.

(162) Repeat for the human skeleton

REVISION QUESTIONS

350 Account for the fact that the skull of a mammal is larger than that of a frog in proportion to the size of the two animals

351 Explain why the thorax of the mammal is protected by ribs, whereas ribs are entirely wanting in the frog

352 Why is it that in the rabbit the clavicle is very small, whereas it is well developed in man? In which other mammals is this bone well developed?

353 What is the special advantage conferred on the mammal by the peculiar structure of the atlas and axis? Are these vertebrae present in the same modified condition in the fish, amphibian, reptile and bird?

354 Why is it that the foramen magnum is on the floor of the human skull, whereas its position is towards the hind end of the skull of other mammals?

355 Construct diagrams to illustrate the plantigrade, digitigrade and unguligrade type of tread from the skeletons of the feet of man, the rabbit and the cow Mention other mammals which illustrate each of these treads

356. To which type of joint does each of the following belong,— the knee joint, the shoulder-joint, the wrist-joints, joints between the phalanges, joint between condyles and atlas, joint between atlas and axis, joints between pre- and post-zygapophyses, joints between centra, symphysis between the pubes, joint between frontal and parietal?

CHAPTER 38

MAMMALIA (Contd)—THE NERVOUS SYSTEM—BRAIN—CRANIAL NERVES—SPINAL CORD—SENSE ORGANS—ORGANS OF TOUCH, TASTE AND SMELL—THE EYE—THE EAR

Material for Study Heads of rabbits preserved as directed in Sect 361 , t. s. spinal cord of rabbit or rat , a human brain

428. Dissection of Rabbit's Brain.—The nervous system consists of the essential parts as in the frog, and its functions in the two animals are also similar. However, the brain of the mammal is very much more advanced than that of the frog, and deserves special attention.

Practical work

On account of the extreme delicacy of the tissue the greatest possible care should be taken in dissecting the brain as well as in handling it after dissection Cut off the bones of the roof of the skull beginning at the foramen magnum. Crack the sides of the skull by means of a pair of bone-forceps and remove the broken bits of bone Note that the entire brain is covered in a tough strong membrane, the **dura mater.** Carefully remove this membrane from the portions so far exposed. Now lift off the brain, beginning at the medulla oblongata, from the floor of the skull,

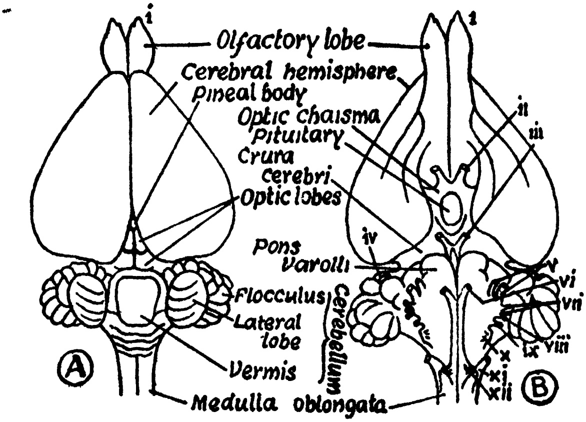


Fig 129 The brain of the rabbit **A**, dorsal and **B**, ventral view. i to xii, the roots of the twelve cranial nerves

carefully cutting the nerve roots, pair after pair, so as to leave as much of their length as possible attached to the brain. Note that the dura mater is left behind with the floor of the skull. The **pia mater** is a much thinner membrane closely applied to the outer surface of the brain and penetrating into every crevice in the surface of it. Blood vessels of the brain run under this membrane.

429. Brain of Frog and Rabbit.—(Figs. 35 and 129) Procure the brain of a frog, for comparison Note that in both the same primary regions are seen Beginning at the posterior end in the rabbit's are the almost cylindrical **medulla oblongata ;** the much lobed **cerebellum,** dorsal and anterior to the medulla, the large pair of **cerebral hemispheres** in front of the cerebellum, and the **olfactory lobes** projecting at the anterior end, but starting from below the hemispheres The **diencephalon** and the **optic lobes** are seen when the cerebral hemispheres and the cerebellum are pushed apart, to lie deep down between the two The diencephalon is surmounted by a **pineal body.** On the ventral side are seen in addition the **optic chiasma** in the middle of the cerebral region, and immediately behind it is a small median elevation which is the **pituitary body.**

(163) Sketch the dorsal and ventral views of the brain of the rabbit.

Make a sagittal section of one of the brains, and a series of transverse sections of another (Two students can conveniently work together.) Arrange the sections in order on a dark background such as a sheet of black paper. With the help of Table 16, make out the parts, comparing them at the same time with the brain of the frog, on the one hand and the human brain on the other.

TABLE 16

THE BRAIN OF THE FROG, RABBIT AND MAN COMPARED

REGION & PART OF BRAIN	FROG	RABBIT AND MAN
Fore-brain		
Olfactory Lobes	Large in proportion to size of brain	Small in rabbit and very small in man in proportion to rest of brain.
	Halves united mesially	Halves independent
	Placed entirely in front of cerebrum	Greater length overhung by cerebrum in rabbit. Completely overhung in man

Cerebrum	Hemispheres small, a third of entire brain	Hemispheres large, a half of the brain in rabbit and about 9/10 of the brain in man
	Surface smooth	Few grooves on surface in rabbit
		Surface highly convoluted in man with many **sulci** (ridges)and **gyri** (grooves).
	Hemispheres not united mesially	Hemispheres held together by a broad band of nerve matter called **corpus callosum** and by the **anterior, middle and posterior commissures** (See I s and Fig 107)
	Hemispheres placed between olfactory lobes and diencephalon	Hemispheres grow forward over olfactory lobes and backwards over diencephalon and optic lobes. Meet the cerebellum behind
Diencephalon	Large rhomboid area as seen from above	Completely overhung by cerebrum above
	Pineal stalk alone present	The epiphysis (pineal body and its stalk in the form of a hollow conical uppushing) is present
	Infundibulum downwards and backwards Pituitary body large and not fused to infundibulum	Infundibulum downwards Pituitary small and fused with infundibulum.
Mid-brain		
Optic lobes	Single pair called corpora bigemina, exposed, large.	Two pairs called **corpora quadrigemina,** completely covered by cerebrum, small in proportion
Crura cerebri	Thinner	Comparatively thicker
Hind-brain		
Cerebellum	A mere transverse ridge	Well developed with surface drawn up into folds Consists of five lobes, a median **vermis,** paired **lateral lobes** and paired **flocculi** on sides of lateral lobes Flocculi absent in man
Pons Varolii	Absent	A transverse band of nerve matter below thick floor of hind-brain connecting lateral lobes of cerebellum
Medulla Oblongata	Large, as thick as cerebrum	Small in comparison to rest of the brain
Cranial Nerves	Ten pairs (See Sect 103)	Twelve pairs. (See Sect 432)

430. Ventricles of the Brain.—An examination of the transverse sections of the brain shows that the ventricles of the brain are very much more reduced than in the frog (Fig 36), owing to the great development of the walls, especially the side walls. Thus the cerebral ventricles, the 3rd ventricle, the infundibulum and the optic ventricles are mere chinks extending dorso-ventrally. The iter, however, is retained as a fairly wide passage with a thin roof and thick floor, and extending from side to side. The 4th ventricle is large as in the frog.

(164) Sketch selected t. sections and the sagittal section of the brain.

431. Transverse Section of the Spinal Cord.—Examine the transverse section of the spinal cord of the rabbit or any other mammal under the microscope. Make out all the parts already seen in the transverse section of the spinal cord of the frog (Fig. 37), noting also the differences in details.

(165) Sketch.

432. The Cranial Nerves.—In reptiles, birds and mammals there are 12 pairs of cranial nerves, while in the fishes and amphibians there are only 10 The first ten cranial nerves of the rabbit are homologous to the ten cranial nerves of the frog and have similar origin, relations, and distribution. The eleventh is called the **spinal accessory,** and the twelfth is homologous to the first spinal of the frog, which, however, now arises from the medulla oblongata. It is called the **hypoglossal.**

In Sect 106 we have seen that the spinal nerves consist of afferent and efferent nerve fibres. In the case of the cranial nerves, however, since most of the important sense organs are lodged in the head, we find that some of them are purely sensory, i e., contain only afferent fibres. Others are purely motor, while yet others are mixed like the spinal nerves and contain both afferent and efferent fibres. The resemblance of this third category, viz , the mixed, to the spinal nerves is enhanced by the possession of a ganglion in connection with their roots

A more amplified table of the cranial nerves than the one in Sect. 103 is given below

TABLE 17

CRANIAL NERVES OF A MAMMAL

SERIAL NO	NAMES OF NERVES AND BRANCHES	ORIGIN	DISTRIBUTION	NATURE
I	**Olfactory**	Olfactory lobe	Epithelium of nose	Sensory
II	**Optic**	Optic lobe	Retina of eye	Sensory
III	**Oculo-motor**	Crura cerebri	Superior, Internal, and Inferior recti and inferior oblique muscles of eye	Motor
IV	**Trochlear (Pathetic)**	Between optic lobes and cerebellum	Superior oblique muscle of eye	Motor
V	**Trigeminal**	Side of Medulla (Gasserian ganglion)		
	Ophthalmic		Skin of upper part of face	Sensory
	Maxillary		Skin of snout and virbissæ	Sensory
	Mandibular		Lower jaw muscles, teeth of lower jaw and taste buds of tongue	Motor Sensory Sensory
VI	**Abducens**	Ventral side of medulla	External rectus muscle of eye	Motor
VII	**Facial**	Side of medulla (same as for V)		
	Hyomandibular		Face muscles, hyoid, pinna of ear	Motor
	Palatine		Palate, floor of nose	Sensory
	Corda tympani		Salivary glands	Secretory
VIII	**Auditory**	Side of medulla	Membranous labyrinth	Sensory
IX	**Glossopharyngeal**	Medulla (vagus ganglion)	Sides of pharynx Taste buds of Posterior half of tongue	Motor Sensory
X	**Vagus (Pneumogastric)**	Same as for IX		
	Anterior laryngeal		Anterior side of larynx	Motor
	Posterior laryngeal (Recurrent)		Posterior side of larynx	Motor
	Cardiac		Heart	Motor
	Pulmonary		Lungs	Sensory
	Gastric		Oesophagus, stomach	Motor
XI	Spinal accessory	Medulla	Neck muscles	Motor
XII	Hypoglossal	Medulla	Tongue muscles, neck muscles	Motor

The spinal nerves and sympathetic nerves are arranged in the rabbit on much the same plan as in the frog, though the number of spinal nerves is larger in proportion to the number of vertebræ.

433. Sensations.—We speak of a sensation when an afferent impulse reaching the central nervous system gives rise in us to a feeling by which we know that something is happening In order to produce a sensation three distinct conditions are necesssary : (1) Some disturbing condition which stimulates one or more sensory organs, (2) the transmission of the stimulus along sensory fibres to the brain and (3) the translation of the irritation by the brain into what we call consciousness.

Some of the sensations make us aware of the state of or changes in our surroundings and are called the special sensations, while others make us aware of the general condition of our body and are called the common or **general sensations.** The latter include shuddering, shivering, warmth, hunger, fatigue, faintness, etc The muscular sense, another general sensation, enables us to regulate the contraction of muscles with extreme precision and perform the most complicated actions even without the aid of sight It is this sense that enables us to estimate the weight of an object by the effort required to lift it. ✓

434. The Sense Organs.—The Mammalian sense organs are essentially the same as the Amphibian ones we have studied earlier. Mammals, however, possess different kinds of tactile corpuscles and taste-buds, their olfactory passage is much complicated by the formation of turbinal bones over which the olfactory epithelium is spread out, and the tympanic membrane of their ear more deeply placed and connected with the inner ear by three bones in place of the single columella of the Amphibia

435. Tactile Corpuscles.—In Fig 121, A is shown a tactile corpuscle placed within a papilla of the dermis, known as **Meissner's corpuscle** after the discoverer This consists of an elongated bulb made up of a number of cells upon which the terminal branches of the nerve fibres are wound in an irregular branching spiral. These corpuscles occur, in man, most numerously in the papillæ of the skin of the palm, especially of the finger-tips and are common on parts of the skin where there is no hair, Placed in simiar papillæ of the dermis are another kind of tactile corpuscles known as end-bulbs or **Krause's corpuscles,** smaller than the Meissner's corpuscles, globular and consisting of an outer capsule and a mass of polygonal cells in it Nerve fibres enter the capsules and break up like capillaries in a glomerulus. These are found on the lips.

A third kind of corpuscle, not strictly tactile, is the **Pacinian corpuscle,** being found on the branches of the nerves which supply the hands and feet as they pass through the sub-cutaneous tissue They are long, oval, bulbous structures, 1/10 inch long, consisting of an elongated central core of transparent cells enclosing the termination of the nerve The core is surronded by several layers of connective tissue, like the coats of an onion, with an outermost coat formed of a continuation of the neurilemma of the nerve fibre Their deeper position suggests that they have more to do with the reception of pressure stimuli rather than with tactile stimuli

The **hairs** all over the body, and especially the vibrissæ also act as organs of touch

436. The Organ of Taste.—The human taste organs are located in certain portions of the epithelium of the tongue and the palate. They take the form of papillæ In man, these are abundant on the upper surface and back of the tongue and the posterior part of the palate. They are of three different kinds, long slender ones called **filiform** papillæ closely packed together over the front and sides of the tongue, **fungiform** papillæ (Fig 40, B), broad at their outer ends and narrow at their inner ends and scattered about among the filiform ones, and **circumvallate** papillæ found at the back of the tongue, taking the form of discs when superficially examined. At the sides of the second and third kinds, the epithelial cells are arranged in special groups called **taste-buds** to whose inner ends are attached the gustatory nerves.

437. The Organ of Smell.—The sense of smell, no doubt, plays a far more important role in the mammals than in perhaps, any other class or vertebrates. Hence, while the essential parts remain the same as we have seen in the frog (Sect 118), the area of the lining of the nostril is very much increased by the formation of the turbinal bones (Sect. 420) projecting into the nasal passage. These are scrolls of bone covered over with the olfactory epithelium The increase in area of the olfactory epithelium (without a corresponding increase in the size of the organ) renders it a more effective smell-perceiving organ than in the frog. In man the sense of smell is not so well developed as in the rabbit

438. The Human Eye.—(Fig 130) The structure of the human eye may be taken as typical of the mammalian condition, and indeed it differs but little from the eye of the frog and other vertebrates in essential features (Sect 119) In mammals the eye-lids are well developed and movable and fringed with eye-lashes. The nictitating membrane is represented by the red patch of tissue in the inner corner of the eye of man, while in the rabbit it is well developed and movable The eye muscles are the same as those of the frog (Sect. 121) except that the levator and rectractor muscles are absent.

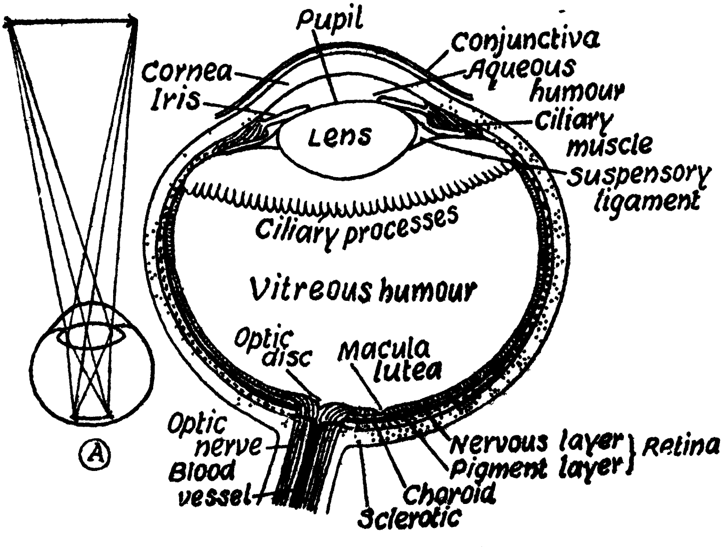


Fig. 130 The human eye in horizontal section through the optical axis. **A**, formation of an image on the retina.

The eye is lodged in the socket of the eye or orbit, which in addition to the eye-ball contains accessory structures like the eye-muscles, lacrimal apparatus, fatty tissue, etc. The eye-ball is covered in front by the upper and lower eye lids. The inner lining of the eye-lids, called conjunctiva, is reflected over the front of the eye-ball as a thin transparent membrane. This portion is kept clean and moist by the secretion of the tear- or **lacrimal gland** placed in the upper and outer portion of the front of the eye-ball

The eye ball is a globular structure consisting of three distinct coats, the sclerotic and cornea, the choroid and the retina. (1) The **sclerotic** is the outermost resistant and opaque coat made of white fibrous connective tissue covering the entire surface except about a sixth in front, viz., the **cornea,** a transparent horny portion, continuous with the sclerotic and forming a slight prominence at the front or exposed part of the eye-ball. It has a smaller radius of curvature than the sclerotic The optic nerve enters behind the sclerotic through an aperture in its wall. Next inside the scleroic is (2) the **choroid,** consisting mostly of blood-vessels and connective tissue, with dark pigment-cells Under the region where the sclerotic passes into the cornea, a muscular body called the **ciliary muscle** connects the choroid with the iris Just before the choroid reaches the edge of the cornea, it becomes raised into a number of ridges called **ciliary processes** Their function is to secrete the aqueous humour The **iris** is the dark, grey or blue circular curtain that is seen through the cornea It is made of radial and circular muscle fibres by the contraction of which it is able alternately to dilate and contract the aperture in its centre, called the **pupil.** The pupil contracts when exposed to a bright light, and dilates when there is comparative darkness (3) The **retina** is a delicate membrane lining the choroid, except in the region of the ciliary processes It consists of the expanded fibres of the optic nerve and connective tissue It is, therefore, the sensitive part of the eye. Just opposite the pupil and slightly lateral to the point of entry of the optic nerve is the **macula lutea** or yellow spot where the retina is thinnest. This is absent in the rabbit. It is the spot of most distinct vision. Where the optic nerve enters the eye the retina is insensitive and is called the blind spot or **optic disc.** Touching the iris on its hinder surface is a biconvex, transparent solid body called the **crystalline lens.** It is closely invested by a thin transparent membrane or **capsule,** and is held in an elastic frame called the **suspensory ligament** extending on its outer margin to the ciliary processes of the choroid. The ligament has the function of keeping the lens in a state of tension. When the ciliary muscles contract and pull the choroid forward, the ligament is relaxed and causes the lens, which is elastic, to shorten its diameter, i. e., increase its radius of curvature The cavity between the cornea and the iris is filled with a watery fluid called the **aqueous humour,** and the large space bounded by the lens in front and the retina behind is filled with a gelatinous fluid of glassy transparency called **vitreous humour,** which keeps the eye-ball blown out.

439. The Structure of the Retina.—(Fig 131) The sensitiveness of the retina to light is due to the presence in it of certain modified cells called **rods and cones**. The outer region of the thickness of the retina consists of black pigment cells which form an effective screen preventing the light from diffusing into the outer walls of the eye. The rods and cones are placed immediately inside the pigment layer into which their ends are actually embedded. Next inside is a layer of bipolar nerve-cells with short arborising processes. Finally, there is layer of nerve-cells whose dendrons are directed towards the bipolar cells and whose axis cylinders become the fibres of the optic nerve From all over the retina these fibres are gathered into the optic nerve Note that where the optic nerve enters the eye ball there could be no sensitiveness This portion is therefore 'blind' and is hence called the blind spot The various elements of the retina above mentioned are held together in place by supporting connective tissue or neuroglia

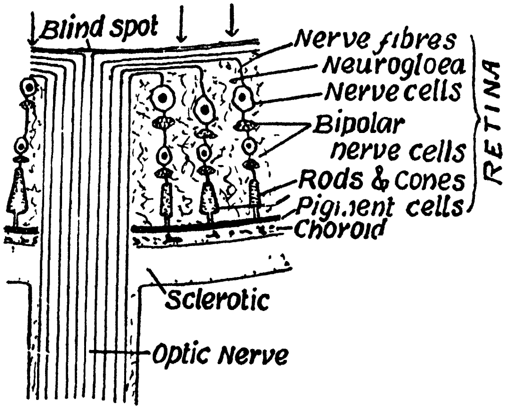


Fig 131 Diagram to show the structure of the retina The arrows indicate the direction of light rays falling upon the retina

440. Formation of an Image.—(Fig. 130, A) The eye can be compared to a photographic camera in which, instead of adjusting the screen to receive the images, the lens is adjusted by increasing or decreasing its focal length, in which the inside of the camera is filled with a transparent fluid and in which there are two lenses, one in front of and one behind the diaphragm The immovable screen corresponds to the retina, the darkened sides of the camera to the pigmented wall of the eye-ball, the lenses of the camera to the crystalline lens and the cornea, the diaphragm to the iris, and the aperture of the diaphragm to the pupil. The functions of each of these parts will now be obvious Light from any object in front of the eye falling upon it will pass through the cornea and the aqueous humour, and reach the crystalline lens through the pupil. If the object is well lighted as in the bright sunlight, the pupil will contract so as to allow only a part of the rays that reach the eye to enter the lens. If, on the other hand, the object is but faintly lighted the pupil will dilate and allow more of the rays from it to enter the eye. Thus the iris helps to form a well defined image on the retina, firstly by allowing the light to pass through only the centre of the lens and secondly by regulating the number of rays that enter the eye. The rays passing through the pupil are already converging towards the focus of the cornea and aqueous humour (which together act like a convex lens), but as they now have to pass through the crystalline lens, the point at which they converge is brought nearer to the system of lenses In other words the crystalline lens by refracting the rays again reduces the focal length and assists the formation of a clearly defined image on the retina which corresponds to the screen of the camera

441. Accomodation —The lens of the eye is normally adjusted for distant vision, and when a near object has to be seen the eye has to be accomodated* Accomodation is effected by increasing the refractive power of the crystalline lens so as to reduce the focal length and bring the image to fall exactly on the retina As already indicated this change is brought about by the ciliary muscles contracting and allowing the suspensory ligament to relax This results in the lens becoming more convex, particularly on the front side. The process is regulated by the nervous system so as to bring about just the right amount of contraction or relaxation of the muscle that would make the image fall sharply defined on the retina

In the case of short-sight (myopia), the optical axis of the eye is longer than normal, so that the image falls a little in front of the retina In order to correct the defect and get a sharply defined image on the retina, the refractive power of the lens has to be decreased by means of a pair of concave lenses or spectacles. On the other hand, in the case of long-sight (hypermetropia), the optical axis is shorter than normal, the image falls behind the retina and the defect is corrected by a pair of convex glasses

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* Accomodation is not possible in the frog's eye in which the lens is round and the ciliary muscles and the suspensory ligament are but feebly developed. The frog can therefore see only near objects clearly while on land,

442. The 'Blind Spot.'—The yellow spot (macula lutea) is the area of most distinct vision and the image has to fall on it in order that we may see an object most clearly. On the other hand no vision is possible when the image falls on the blind spot This can be demonstrated by the following simple means Close the right eye and look steadily on the right dot below with the left eye, holding the paper at a distance of a foot.

● ●

Gradually bring the paper near to the eye which is still fixed on the right dot. At a distance of about six inches from the eye it will be seen that the left dot will suddenly disappear owing to its image falling on the blind spot and reappear when the image leaves it

443. The Ear.—(Fig. 132) The mammalian ear marks a definite advance on the ear of the frog. It consists of three parts, the outer, middle, and inner ear Of these, the first two are accessory to the third or essential part The essential organ is the inner ear or **membranous labyrinth** (See Sect. 123) consisting of the same parts as in the frog, viz., a utriculus, a sacculus and three semicircular canals The ductus endolymphaticus is short and does not leave the periotic bone in which the organ lies The membranous labyrinth of the mammal is, however, remarkable for the great development of the **cochlea** which extends from the ventral end of the sacculus as a long spirally twisted outgrowth lying internally to the main organ The membranous labyrinth lies in an excavation of the periotic bone called the **bony labyrinth.**

The middle ear or **tympanic cavity** corresponds to the tympanic cavity of the frog It is, however, placed deeper in the head than in the frog. It communicates with the mouth by the Eustachian tube In it lie the three **auditory ossicles** (Sect 420), viz., stapes, incus and malleus, of which only the first is represented in the frog by the columella. These ossicles form a chain bridging the tympanic cavity. The inner end of the stapes fits into a passage, the **fenestra ovalis,** through which the bony labyrinth would communicate with the tympanic cavity if the stapes were removed from its place. The malleus is attached to the inner side of the **tympanic membrane.**

The outer ear or **pinna** is characteristic of the mammals, and the auditory passage or **meatus** leads from the pinna to the tympanic membrane which lies at its bottom forming a tightly stretched partition between the outer and middle ears

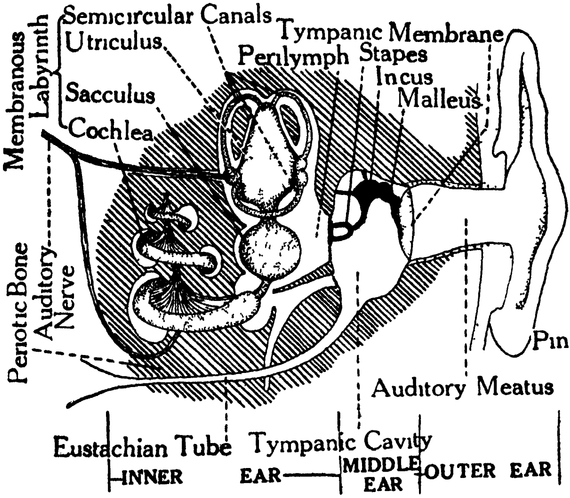

Fig. 132. A diagrammatic section across the human ear

In most mammals the pinna is movable and serves as a sound-collecting ear-trumpet. The vibrations of sound reach the tympanic membrane and are passed along the chain of ear-ossicles and reach the perilymph in which the membranous labyrinth is placed From the perilymph they are transmitted to the endolymph in which are calcareous particles or otoliths like those of the frog The lining of the cochlea is of cells similar to those which form the acoustic spots of the ampullae of the semicircular canals and this is the sensitive portion of the ear, supplied by fibres of the eighth cranial nerve.

As in the frog the function of equilibration of the body is performed by the semicircular canals and their ampullae The highly developed and complex cochlea of mammals containing a very delicate organ, called the **organ of Corti,** is supposed to be the part concerned with the reception of sound vibrations in the mammals in whose lives sound undoubtedly plays a far greater part than in those of Amphibians

REVISION QUESTIONS

357 Clearly distinguish between afferent and efferent nerves

358 How does a sympathetic nerve fibre differ from a peripheral nerve fibre ?

359 What is the relation between brain development and intelligence as far as the frog, the rabbit and man are concerned ?

360 Explain why the mammals as a class possess better developed sense organs than the frog ?

361 Is there any relation between the ability to masticate the food and the degree of development of the sense of taste ?

362 What do you mean by the power of accomodation of the eye ? Explain why accomodation is characteristic of animals that live in the airy medium

363 Enumerate the points in which the mammalian ear shows modification over the ear of the frog

364 Compare the eye of the frog with the human eye and account for the structural differences met with in the latter

365 Construct diagrams showing how short-sight and long-sight can be corrected by the use of proper lenses

366 Mention some of the reasons that have helped the Mammals to a dominant position among the vertebrates

CHAPTER 39

MAMMALIA (Contd)—REPRODUCTION—PROTECTION, NUTRITION AND RESPIRATION OF THE EMBRYO—FOETAL MEMBRANES AND PLACENTA

CHARACTERS AND CLASSIFICATION OF CHORDATA

444. Fecundation.—Most aquatic animals lay immense numbers of eggs which are fertilised by chance by free-swimming spermatozoa shed into the water by the males of the species. In terrestrial animals this kind of casual fertilisation is out of the question, since spermatozoa cannot move on land and would soon dry up and die in that medium Besides, if fertilisation is to be effected it should precede the formation of the thick protective shells characteristic of the eggs of the reptiles and birds. The mammals alone, among the terrestrial vertebrates, have minute yolkless and shell-less eggs which will not at all be able to survive, much less develop, in the land medium. It becomes necessary therefore for the terrestrial vertebrates to have some means of bringing the sperms into close proximity to the ova so that fertilisation may be ensured. Associated with this fundamental need of effecting syngamy are the development of the copulatory organs, and a number of sex-phenomena both physiological and psychological associated with the periodicity of sexual activity, the mutual attraction of the sexes and the act of copulation or coition in which the spermatozoa are transferred into the female genital tract swimming up which they encounter and fertilise the ova, before they get coated with albumen or white, shell-membrane and shell.

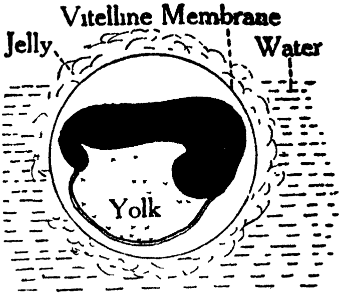

Fig 133 A diagrammatic sagittal section of the embryo of the frog as it floats in water

445. Development.—The fertilised ova require a watery medium in which to undergo development They also require food and oxygen for their metabolic activities and have to be protected from shocks, jolts and enemies It will be noted that in the case of the frog all these requirements are answered, by the watery medium, the food-yolk stored in the egg, by the oxygen in the water and atmosphere and by the jelly floating on water (Fig 134) In the case of the embryos of terrestrial vertebrates the needs are the same as those of the aquatic embryos In all of them, the embryo early in development gets surrounded by a membranous envelope developed from the region surrounding it, called the **amnion** (Fig 134) A watery fluid is secreted into it and it thus serves as a water-cushion in which the extremely fragile and delicate embryo can develop unaffected by the shocks and jolts to which the entire egg may be subject Respiration is subserved by a membranous sac called the **allantois** growing out from the hind end of the embryonic gut and spreading out over a considerable part of the inside of the porous shell and provided with capillaries of the embryo's vascular system In the reptiles and birds (Fig. 134, A) the large store of yolk ensures plenty of nutrition till the time of hatching In mammals, on the other hand (Fig 134, B), there is no yolk in the egg and nutrition is carried on by means of a peculiar structure called the **allantoic placenta,** a modification of the allantois, which establishes intimate relation with the inner lining of the uterus of the mother. The egg-shell of the reptilian and avian eggs are a means of protection. In addition, the eggs may be deposited in holes or nests by the mother and often guarded by her, thus minimising the danger from enemies. In the mammals, not only food, but also protection is afforded by the fact that eggs do not leave the body, but develop in the uterus of the mother itself.

446. The Placenta.—(Fig. 135, B) The allantois of the mammalian embryo comes into contact with the outer embryonic membranes (which in turn are in contact with the mucous membrane of the uterus of the mother) and the two fuse to form the **true chorion.** The true chorion sends out a number of villi or processes that are received into corresponding depressions of the uterine wall so as to establish a very close connection between the embryo and the mother. This compound structure formed by the embryonic and maternal tissues is called the placenta The capillaries of the embryonic part of the placenta receive nutriment and oxygen from those of the maternal part of it by diffusion, and pass them on to the general embryonic circulation, thus providing for the growth of the embryo, during the intra-uterine life.

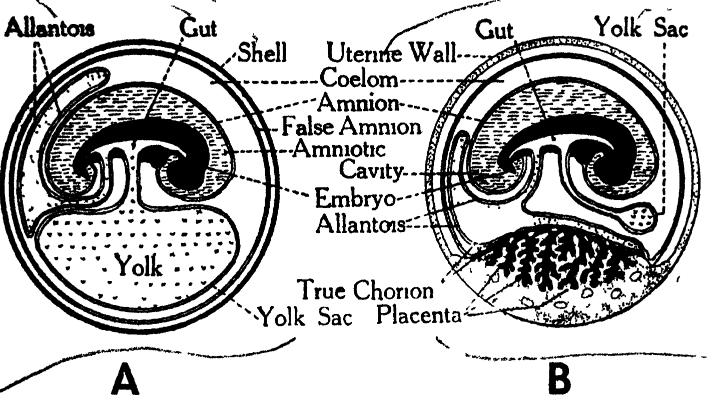

Fig 134 Diagrammatic sagittal sections of **A**, a Sauropsidian (Reptile or Bird) embryo, and **B**, a Mammalian embryo inside the uterus

The union between the maternal and embryonic portions of the placenta may be very intimate, so that at birth the maternal portion is torn off with the fœtus as the after-birth. Such a placenta is known as **deciduate** in contrast to the **indeciduate** placenta in which the villi come clean off the uterus. The latter type is found in the

Ungulates and Edentata (See Sect. 449); in most other mammals the placenta is deciduate

The extent of the chorionic villi on the surface of the embryo varies widely When they are found all over the chorion, we get the **diffuse** placenta, found in pigs, horses, whales and porpoises; when a small portion is smooth and free from villi, we call it **bell-shaped** as in some Edentates and Lemurs. By the extension of the free surface, and confining the villi to a circular patch only, we arrive, at the **discoidal** type, characteristic of the rabbit and other rodents man, the higher apes, insectivores, and bats In the lower monkeys there are two such discs placed at opposite poles This is called placenta **discoidea duplex.** When there are several small discs like so many buttons, it is called **cotyledonary,** and this is found in the ruminants. Finally, if there are two smooth areas at opposite poles with a broad ring bearing villi in between we have the **zonary** placenta as in carnivores and elephants

447. Characters of Chordata.—The shark, the frog, the snake, the pigeon, the rabbit and man belong to the Phylum Chordata, which are bilaterally symmetrical Coelomata, with metamerism well-marked in the embryo, but more or less lost in the adult, they have a dorsal tubular nerve cord, an axial supporting notochord (Sect 151) either during the embryonic stage or throughout life and paired gill-clefts at least in the embryo

The more primitive Chordates (Sect 203) comprise the three Sub phyla, viz, Hemichorda (e g, *Balanoglossus*), Urochorda (e. g, the sea squirts) and Cephalochorda (*Amphioxus*). The rest of the Chordata form the Sub-phylum Craniata or Vertebrata and include the better known Chordates.

448. Characters of the Sub-Phylum Craniata.—These are Chordata in which the spinal cord is expanded in front into a brain, the axial notochord is replaced partially or wholly by a metameric vertebral column forming the axial skeleton of the animal, the brain is protected by a skull or cranium (hence the name) and the nerve cord by neural arches arising from the centra of the vertebræ and placed dorsal to them. Two pairs of appendages (fins or limbs) are present in all except the Cyclostomes, the snakes and a few fishes, amphibians and lizards An internal skeleton of cartilage or cartilage and bone is present.

449. Classification of *Craniata —The Craniata are classified into two divisions and five classes

A. Division Anamnia. Craniata which breathe by gills throughout their post-embryonic life, or at least in the larval stage, embryonic development typically in water, poikilothermous Include the Cyclostomes, fishes and Amphibians

i. Class Cyclostomata. Gill-breathing Anamnia in which the mouth lies at the bottom of a sucker-like funnel and is devoid of jaws and true teeth Paired appendages are absent, but median fins are present and are supported by cartilaginous fin-rays The vertebral column is very imperfectly formed, with a persistent notochord The olfactory organ is single and median Example — *Petromyzon*, the lamprey

ii. Class Pisces (Fishes) Gill-breathing Anamnia possessing true jaws and teeth, median and paired fins supported by fin-rays The vetebral column is more or less completely formed with remnants of the notochord between the centra The olfactory organ is paired

a. Sub-Class Elasmobranchi Mostly marine fishes with a cartilaginous skeleton, with or without dermal denticles, abdominal pelvic fins provided with claspers in the male, eggs large and yolked, embryo with elongated gill filaments projecting through the gill-clefts

1. Order Selachii (Plagiostomi), with five to seven pairs of gill-clefts not covered by an operculum Include the dog-fishes, sharks, skates and rays Examples —*Chiloscyllium indicum*, a common dog-fish, *Scoliodon palassorah*, a common shark, viviparous, *Pristis*, the sword-fish, a ray, viviparous, *Narcine timlei*, an electric ray, *Trigon benneti*, the sting-ray

2. Order Holocephali, with only four pairs of gill-clefts which are covered over by an operculum on each side Example — *Chimaera monstrosa*, the king of the herrings

b. Sub-Class Osteichthyes, fishes with a more or less ossified skeleton, usually with an exoskeleton of flat dermal scales, gills covered by an operculum. One or two lungs or an air-bladder is generally present.

1. Order Dipnoi, scaly fresh-water fish with gills and lungs Example.— *Ceratodus*, the Australian lung-fish

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*Extinct forms are omitted.

2. **Order Teleostei,** fishes with a more or less completely ossified endoskleton, breathing by gills; eggs minute with prolonged larval life, include the vast majority of modern fish. Examples .—*Acipencer*, the sturgeon, *Clupea*, the herring, *Arius*, a cat-fish.

iii. **Class Amphibia,** Anamnia which breathe by gills at least in larval life, median fins when present not supported by fin-rays, paired appendages usually present and of the limb-type (pentadactyle).

1. **Order Gymnophiona.** Vermiform limbless Amphibia with minute dermal scales, tail short or absent, adult terrestrial and burrowing The Coecilians Example —*Uræotyphlus*

2. **Order Urodela**. Scaleless Amphibia with a well developed tail, usually with two pairs of limbs, with or without external gills and two pairs of gill clefts in the adult Examples —*Nectrurus*, with three pairs of external gills and two pairs of gill-clefts, *Salamandra*, the salamander without gills or gill-clefts in the adult, terrestrial.

3. **Order Anura (Batrachia)** Scaleless Amphibia without tail, gills or gill-clefts in the adult with two pairs of limbs invariably present in the adult Examples --*Bufo melanosticus*, the common toad, *Rana tigrina*, the common tiger frog

B. **Division Amniota.** Typically terrestrial Craniata which breathe throughout adult life by means of lungs and never by gills, embryonic development typically on land, embryo protected in an amnion and provided with an allantois or embryonic respiratory organ An epidermal exoskeleton always present

i. **Class Reptilia.** Poikilothermous Amniota with an exo skeleton of epidermal scales, large yolked eggs with a shell

a. **Sub-Class Rhynchocephalia.** Lizard-like Reptiles with five-toed fore and hind-limbs and devoid of copulatory organs. Includes the single genus *Sphenodon*, found on certain small islands in the Bay of Plenty.

b. **Sub-Class Lepidosauria (Squamata).** Reptiles possessing copulatory organs, with the quadrate more or less movably articulated to the skull Include the lizards and snakes

1. **Order Lacertilia.** Lepidosauria usually with two pairs of limbs adapted for walking, the rami of the lower jaw uniting in a median symphysis, movable eye-lids and a tympanum usually present Comprise the lizards Examples ·— *Hemidactylus*, the house-gecko,

Calotes, the garden-lizard; *Draco,* the flying lizard, *Varanus,* the monitor lizard; *Amphisbaena,* a limbless lizard, *Chamaeleon,* the chameleon.

2. **Order Ophidia,** elongated vermiform Lepidosauria without limbs, rami of jaw united by ligament and allowing of a very wide gape of the mouth, maxillæ, palatines, and pterygoids as well as the quadrate are movably articulated, movable eye-lids and tympanum are absent Comprise the snakes Examples —*Python,* the Indian python, *Zamenis,* the rat-snake, *Naja,* the cobra, *Hydrophis,* a sea-snake, *Vipera,* a viper

c. **Sub-Class Crocodilia,** large sized Reptiles, with rows of bony sculptured scutes on the dorsal side, a heart with the ventricle divided into right and left by a complete partition, a hard palate and teeth set in sockets, a median penis and a cloacal opening elongated in the direction of the median axis Examples —*Crocodilus,* the crocodile *Gavialis gangeticus,* the Gangetic crocodile

d. **Sub-Class Chelonia,** Reptilia with the body enclosed in a shell of compactly articulated dermal bony scutes, with which the vertebrae of the back are immovably united, teeth entirely absent, the jaws being invested in horny beaks, a median penis present, cloacal opening longitudinal or circular Include the tortoises and turtles Examples — *Nicoria trijuga,* a common tortoise, *Chelone midas,* the green or soup turtle, marine, *Emyda,* a river turtle.

ii. **Class Aves** (Birds) Homoiothermous Amniota covered with feathers, bipedal, the fore-limbs being modified into wings Teeth absent, the jaws being covered by horny beaks or rhamphothecæ. The heart is divided into right and left halves by a complete partitions of the ventricle as well as of the auricle and the right aortic arch alone persists, large yolked eggs with a shell

1. **Order Ratitæ.** Flightless birds with feathers which have free barbs, and without apteria, the wings reduced and incapable of flight, the sternal keel absent. Examples —*Struthio camelus,* the ostrich.

2. **Order Carinatæ,** birds in whose feathers the barbs are united together into vanes There are pterylæ and apteria and a sternal keel is present except in some flightless species. Include the flying birds. Examples :—*Columba,* the pigeon, *Gallus domesticus,* the domestic fowl.

iii. **Class Mammalia.** Homoiothermous amniota, with an epidermal skeleton of hairs, with mammary glands, red blood-corpuscles without nuclei, embryo nourished during development by diffusion from the maternal blood by means of a placenta (with few exceptions), thoracic cavity separated from abdomen by a diaphragm, and the left aortic arch alone persistent

a. Sub-Class Prototheria, egg-laying primitive mammals, with yolked egg , mammary glands devoid of teats

1. Order Monotremata, with characters of the sub-class — Examples —*Ornithorhynchus*, the duck-bill platypus, Australian,

b. Sub-Class Eutheria, the viviparous mammals, mammary glands with teats.

a'. Super-Order Didelphia (Marsupialia), Eutheria with teats usually enclosed in a marsupium or pouch in which the young which are born in an immature condition attain their full development, an allantoic placenta usually absent The marsupials Example —*Macropus giganteus*, the kangaroo, Australian

b'. Super-Order Monodelphia, Eutheria in which the young are born in a fully developed condition There is an allantoic placenta. The placental mammals.

1. Order Edentata, with incomplete dentition, armed with large curved claws , Examples —*Myrmecophaga*, the ant-eater , *Manis*, the pangolin

2. Order Insectivora, small clawed insectivorous mammals with small incisors and pointed molars. Examples —*Talpa*, the mole , *Crocidura*, the musk-rat , *Erinaceus*, the hedge-hog

3. Order Rodentia, clawed mammals with the incisors elongated, chisel-like, and growing from persistent pulps. The rodents. Examples —*Mus*, the rat; *Lepus*, the hare and rabbit, *Sciurus*, the squirrel , *Hystrix*, the porcupine

4. Order Chiroptera, clawed mammals with the fore-limbs modified as wings The bats. Example — *Pteropus*, the flying fox

5. Order Carnivora. Clawed mammals, with enlarged, pointed and recurved canines. The cats, dogs, bears, seals, sea lions, etc Examples —*Felis*, the cat ; *Canis*, the dog , *Melursus*, the sloth-bear ; *Phoca*, the seal.

6. **Order Primates,** the nailed mammals, mostly arboreal, the thumb and big toe being opposable. The monkeys, apes and man, Examples.—*Hapale*, the marmoset ; *Ateles*, the spider monkey ; *Cynocephalus*, the baboon, *Gorilla*, the gorilla, *Homo sapiens*, man.

7. **Order Ungulata,** the hoofed mammals, mostly herbivorous, unguligrade, canines usually absent or ill-developed Include the horses, cattle, camels, antelopes, pigs, etc Examples —*Equus*, the horse, *Bos*, the ox, *Sus*, the pig, *Hippopotamus*, the hippopotamus, *Elephas*, the elephant

8. **Order Sirenia,** aquatic with fish-like body, fore-limbs paddle-like, a depressed tail, with no vertical median fin, nostrils dorsal. The sea cows. Example —*Manatus*, the manatee.

9. **Order Cetacea,** large aquatic mammals, with fish-like naked body, fore-limbs paddle like, a depressed tail, nostrils dorsal, snout greatly elongated, a vertical dorsal fin usually present The whales and porpoises Example, *Balaenoptera*, a baleen-whale ; *Orcella*, a porpoise

REVISION QUESTIONS

367 What is the importance of water to the cell, the body, the embryo? Can development of an embryo take place outside a watery medium ?

368 In what fundamental respects does the embryonic development of a mammal differ from that of a bird and of a frog ?

369 What are the advanced features seen in the embryo of a chick as compared with that of a frog ? Explain the need for each such feature.

370 The embryos of all vertebrates, including the terrestrial forms, possess gill-clefts and a noctochord What is the significance of these facts ?

371 The mammalian egg contains no yolk, but a yolk-sac is formed in its development Explain this

372 Which is the primary organ from which the embryonic as well as adult respiratory organs (apart from the skin) of vertebrates are formed ? What is the significance of all of them being derived from that primary organ and no other?

373 How far is it true to say that a chick-embryo develops on land and not in water?

374. Write a short essay on the importance of diffusion in living organisms.

PART IV

THE LIVING ORGANISM

CHAPTER 40

LIVING AND NON-LIVING MATTER—PROTOPLASM—THE CELL—ANIMALS AND PLANTS, HOW THEY DIFFER—THE BALANCE OF NATURE

450. Living and Non-living Matter.—In Sect 54, we have seen that living matter is composed of certain elements, chief of which are O, H, C, N, S, Fe, Ca, K, Na and Ph Living matter has therefore its origin in non-living matter Living matter is being constantly produced from non-living matter, on the one hand, and on the other it is being reconverted into non-living matter This is what is taking place in the metabolic activity of living matter. Non-living matter exists in the form of elements or compounds Living matter exists always in the form of compounds, the molecules of which, compared with those of the non-living, are extremely complex and unstable Living matter has the power of building up more living matter from certain compounds on the one hand, and on the other, of being oxidised into simpler, non-living molecules This constant building up and breaking down of its molecules is the primary characteristic of living matter In the processes of breaking down, the molecules of living matter give out a certain amount of energy, which endows it with the power of automatism As living matter becomes more and more organised into higher and higher forms of life, it expresses itself in newer and newer characters, viz , symmetry, definiteness of shape, limit of size, and limited duration of life of the individual (death) and the faculty of reproduction

451. Characters of Living Beings.—(1) **Chemical Composition.** Living beings are made of living matter or protoplasm, which Huxley has defined as the 'basis of life,' together with certain products of protoplasm such as skeletal structures formed secondarily from it. 99% by weight of it is formed by the elements oxygen, hydrogen, carbon, nitrogen and sulphur, the remaining 1% being formed by the other elements listed above Well over 50% of protoplasm is water. The exact chemical composition of protoplasm is not known and cannot be known by methods known to science, because it is so unstable that any attempt at analysis alters its composition and renders it non-living All that we can know, therefore, is the composition of dead protoplasm Moreover, the protoplasm of different organisms and the protoplasm of different tissues of the same organism are different, so that it is reasonable to think that there is endless variety in the chemical composition of protoplasm We can roughly say that a protoplasmic molecule consists of a very large number, say, a thousand or more atoms (See also Sect 54).

(2) **Microscopic Structure.** When examined under the microscope, protoplasm is seen to be not a homogeneous substance, but a heterogeneous mass, made up of little 'packets' rather inappropriately called 'cells.' Each cell is, say, a hundredth of a millimetre in diameter, and contains two distinct kinds of protoplasm, viz., the cytoplasm and the nucleus, with often other inclusions lying in the former (See Sect. 132) Each cell may also have a cell-wall Protoplasm cannot exist in units of larger size. The reason for this is that metabolism or the chemical activity of protoplasm cannot take place efficiently if it exists in layers of considerable thickness or in large volumes (See Sect 161), since nutrient fluids, oxygen and waste materials can diffuse only through thin layers or minute volumes This explains also the tendency for the cell to divide into two or more smaller cells when it reaches a certain maximum size as the result of growth. It so happens, therefore, whether in the microscopic Cytozoa or in the macroscopic Histozoa, the body is made up of a single *cell* or a larger number of *cells* No living organism is known whose body is not made of a cell or of many cells

(3) **Metabolism.** In order that life may be maintained, it is not sufficient that protoplasm should exist and that it should be parcelled into cells; but it is also necessary that it should constantly be built up from the simpler molecules of nutrient substances available to it (anabolism) on the one hand, and on the other, give up some of its molecules to be broken down into simpler substances by the oxygen of the atmosphere (katabolism). Some of the simpler substances thus produced have to be got rid of from the cell and ultimately from the body or excreted The existence of protoplasm thus involves continuous chemical activity.

(4) **Growth.** Anabolism or assimilation under proper conditions, results in the increase in the volume of the protoplasmic contents of the cell and causes it to grow. As we have seen above growth of

the cell results in cell-division. In the Cytozoa, the daughter-cells separate from each other, so that, in them, growth is confined to the individual cell-bodies ; while in the Histozoa the daughter-cells keep together from the first division of the zygote onwards so as to give rise to a multicellular body, in which growth results from the addition to the number of cells as well as to the substance of each cell.

(5) **Shape.** Increase in the number of cells brings in its train a number of new problems for the Histozoan organism. The foremost of these is the inter-relation between the various cells. Since now there are a large number of cells making up the body of the individual, physiological division of labour is rendered possible and the cells are grouped off for the different functions and occupy the different parts of the body in the form of organs In the earlier stages of the Histozoa, as we have seen in the Coelenterata, when the organism was still in the sedentary stage, and, therefore, the relation of the organism to its surroundings on all sides the same, we see a radial symmetry established. With more active and free-moving habits, which in themselves were a result of higher organisation of the tissues into organs, the radial symmetry is given up for a bilateral one, which characterises all the animals above the grade of the Coelenterata. The actual shape of each species is dependent upon the shape and disposition of its organs, but these are always disposed on the principle of a radial or bilateral symmetry, as the case may be.

(6) **Size.** Another problem arising from growth of the body, which therefore is peculiar to the Histozoa, is the extent to which growth by addition of cells can or must take place In each species we see a limit of size beyond which growth by addition of cells does not take place. What the exact reason for such limitation is, we do not know , but it is possible that the limit is imposed by the inability of the animal or plant organisation to manage the needs of all its constituent cells beyond a certain limit. That the sizes attained by different species is so different need not be considered as an objection, as the protoplasms of different species also differ from each other considerably One thing, however, is certain, viz , for each species there is a limit beyond which the crowding of cells so characteristic of the Histozoa cannot be conducive to the healthy existence and functioning of the individual cells.

(7) **Duration of Individual Existence.** Growth also tends to limit the duration of life of the cells of the body of the Histozoan, thereby limiting the life span of the individual, and causing its death normally after a fixed duration of time Presumably, the crowding of cells reduces the efficiency of their metabolism and excretion, so that the cells of the adult have not got the same vitality as the zygote or the cells of the embryo The Cytozoan cell, on the other hand, continues to live into endless generations, since growth by addition of cells, characteristic of the Histozoan, does not take place in it, and no conditions which interfere with the efficiency of its metabolic activities and excretion ever arise Indeed there is no reason to think that tissues and the whole bodies of Histozoa cannot continue to live indefinitely, if proper metabolism and excretion were assured.

(8) **Reproduction.**—We have seen that reproduction in the Cytozoa is a matter of the fully grown cell-body dividing into two or more daughter-cell bodies In the Histozoa, however, the word reproduction has a different significance. Though in both, reproduction results in the formation of new individuals, the methods adopted are different in the two grades of the animal kingdom. In the Histozoa, we see that cells are grouped into organs for the performance of the different functions of the body Such division of labour involves specialisation in structure of the cells of the body. With specialisation they often lose the power of active cell-division, e. g., the nerve-cells, and if at all they are able to divide they give rise to only specialised cells like themselves. It is obvious then, that none of the specialised cells of the Histozoan body is fit to subserve reproduction, and, therefore, some unspecialised or primordial cells of the zygote have to be set apart and tended in some part of the body, where they remain in a more or less dormant condition till the time they are required for purposes of reproduction Like other cells of the body they are direct descendants of the zygote or fertilized ovum, with the difference that unlike them, the germinal cells retain the unspecialised nature of the protoplasm of the zygote. We have seen above that the tissue-cells are destined to age and die. The germinal cells which remain in the body in a dormant condition, that is, without performing any special function in the body itself, probably retain their vitality unimpaired, or have their vitality restored by syngamy in the act of fertilisation. Anyhow, it is seen that immedi-

ately after syngamy they undergo active cell-division and give rise to a new Histozoan individual with all the tissues and organs characteristic of the species. It will thus be seen, that the body or soma as distinct from the germinal portion of it, i. e, the primordial germ cells, plays only a secondary part, if at all, in reproduction, and that it is the latter alone that carries on from generation to generation, serving as the only link that connects one generation with the next. Looked at from this point of view, the Cytozoan cell-body corresponds to the Histozoan germ-cell

(9) **Power of Adjusting to Environment.**—All living beings show a certain amount of ability to adjust themselves to the surroundings This involves the ability primarily to appreciate what is happening in the surroundings of the organism and secondarily to contract the entire body or some part of it, or secrete certain substances when induced by stimuli received from the surroundings. Thus, an Amoeba on receiving a touch stimulus retracts the part of the body on which the stimulus is received and makes away from the source of the stimulus. If it comes into contact with a particle of food, the stimulus set up thereby induces the animalcule to contract certain portions of its protoplasm so as to engulf the food particle If exposed to drought, heat or cold, the respective stimulus causes not only contraction, but also secretion of a protective cyst

This response to stimuli, of which we have but faint glimpses in the lower animals, becomes well developed in the Histozoa in which a special kind of tissue, viz, nervous tissue, is developed for the reception of stimuli and the transmission of impulses from one part of the body to another

TABLE 18

452. EVOLUTION OF CHARACTERS OF LIVING BEINGS AS EXPRESSED IN THE ANIMAL KINGDOM.—

GRADE OF EVOLUTION OF MATTER	FUNDAMENTAL CHARACTERS	EXPRESSIONS OF THESE CHARACTERS
Non-living Matter	Simple Chemical Composition	
Living Matter	Complex chemical composition	Instability
	Irritability	Contraction, Secretion and other reactions to stimuli
Cytozoa	Katabolism (Respiration)	Excretion
	Anabolism (Nutrition)	Increase in volume
		Division into independent primordial cells
Histozoa		Division into interdependent primordial cells—Increase in size
		Differentiation of cells into tissues
		Organisation—Symmetry—Shape
		Loss of faculty of active cell division
		Limit of size
		Senility of cells—Death
		Active cell division—Reproduction

453. Non-living Beings.—As contrasted with living beings, non-living beings have a more stable chemical composition, and although many of them are subject to oxidation, their continued existence is not dependent upon the balance between the building up and the breaking down of their molecules. Their chemical composition is definite and their microscopic structure homogeneous, unless this homogeneity is secondarily lost by the mixing of different substances. They can grow in size only by the addition of similar substance from without and not by assimilation of dissimilar substance within. They have no characteristic shape, or size, and no limit is set to the duration of their existence, though they may be transformed from one lifeless form to another by physical or chemical forces. As they do not grow like living beings, they are incapable of reproduction, since reproduction is only a phase of growth. Finally, they do not respond in any way to stimuli received from their environment.

454. Living Substance or Protoplasm.—Protoplasm is a fluid or semi-fluid, transparent and colourless substance, which, however, turns opaque and solid after death It reacts to heat, electricity, radiactivity and chemical agents, either in a positive or negative manner Thus an Amœba actively moves about, performing all its vital functions within a certain range of temperature, say, between 25° and 30° C In other words it reacts positively towards heat within this range of temperature If, however, the temperature is raised above 30° or lowered below 25°, the animalcule reacts negatively, that is it rounds itself off and begins to encyst, and if the variation is very great it dies

The exact **microscopic structure** of protoplasm is not known with certainty When viewed under the high power of the microscope, as in the examination of an Amœba, we note innumerable granules in the endoplasm. Some have therefore thought that its structure is **granular.** Others consider it to be **alveolar,** that is, consisting of two substances, one of which is in the form of minute globules embedded in the other Yet others consider its structure to be **reticular,** that is, consisting of a network of living, anastomosing fibres whose meshes are filled with water, fats and other non living substances. As a matter of fact, we know little about the minute structure of protoplasm.

Regarding the **chemical composition** of protoplasm also, we know but little, but what we do know is more definite and well established. 97% of protoplasm consists of the following four elements :—

Oxygen	65·0	parts.
Carbon	18·5	,,
Hydrogen	11·0	,,
Nitrogen	2·5	,,
	97·0	,,

These exist in the form of definite compounds, organic and inorganic. The organic compounds are proteins, carbohydrates and fats Proteins consist of very complex and unstable molecules which always contain nitrogen in addition to carbon, oxygen and hydrogen. They are insoluble in water , hence, when used as food they have to be digested prior to absorption. They soak in water and swell up, like a sponge They are coagulated by heat and various chemical reagents like alcohol This accounts for the hardening of tissues under preservation. Carbohydrates consist of carbon, oxygen and hydrogen, the last two occurring in the proportion in which they unite to form water Common forms of carbohydrates are the starches and sugars, which are produced by the photosynthetic activity of plants , and when found in animals, they are to be traced back to the plant-food of the animal or, in the case of carnivorous animals, to their herbivorous prey Starch, however, is not an essential constituent of protoplasm, like proteid Fats are also of plant origin They are compounds of carbon, hydrogen and oxygen, but the last two are not in the proportion in which they unite to form water.

455. The Cell or Unit of Life.—We have seen that protoplasm exists in the bodies of living beings parcelled out into microscopic packets to which the name cell has been given, though originally the term was used for the cellulose chambers, devoid of protoplasm, as seen under the microscope in a section of cork (dead plant-tissue). With the progress of knowledge it was found that in the living plant, the chambers contained a fluid substance, viz., protoplasm, the name cell being now applied to the contents together with the container.

The protoplasm of a typical cell consists of two main portions, the cytoplasm and nucleus (See Fig. 45). Cytoplasm is the more fluid and transparent portion of the protoplasm of the cell, and is often distinguishable into a clear ectoplasm forming the peripheral portion and a more granular endoplasm within The endoplasm may contain various structures embedded in it such as, vacuoles, plastids, chromidia, and mitochondria. The nucleus is more dense, refractive and embedded in the cytoplasm, and is limited by a nuclear membrane. Inside the nuclear membrane several structures are found Crossing from wall to wall of the nuclear membrane is a network of linin fibres, the meshes of the network being filled with a fluid called plastin Scattered about on the fibres are granules of chromatin, a substance that has a strong affinity for certain stains Several granules of chromatin may form a larger nodule called karyosome One or more bodies called nucleoli may also be embedded in the nucleus Immediately outside the nucleus lies what has been called an attraction sphere (astrosphere) enclosing one or two centrosomes, which are concerned with cell division.

456. Functions of the Nucleus.—If a cell is deprived of its nucleus or cut into two halves, one alone containing the nucleus, the enucleated portion will soon cease to show vital activities and die, while the other portion would continue to live In the division of cells also, the nucleus divides first, its chromatin resolving into chromosomes and then parted equally between the daughter-cells (See Sect 134) The nucleus is thus seen to be concerned both with the normal vital activities and with the reproductive activity of the cell The chromosomes of the nuclei are the bearers of heredity If the enucleated ovum of a certain species of sea-urchin is fertilised by the sperm of another species, development takes place for some time, but the larva shows only the characters of the paternal species The characters of the maternal species could not be inherited, as the maternal nucleus was absent.

457. Interdependence of Cells.—In the Histozoan body, made as it is of a very large number of cells, each cell cannot exist independently of the others.

This interdependence is the result of specialisation of the cells and their organisation into tissues. For example, without the digestive and absorptive cells of the alimentary canal the nutritive needs of the entire community of cells forming the individual cannot be met. For the well-being of the entire body metabolism of each and every cell has to be ensured. This is done by the vascular system which carries digested food and oxygen to the cells on the one hand, and on the other, removes the excretory products from the cells.

458. Animals and Plants.—Animals and plants, being both living organisms, have their bodies made of protoplasm parcelled into cells and products or secretions of the cells. There is, therefore, no fundamental difference between the two. The protoplasm of both exhibit the same essential features.

But, plant-cells secrete a hard **cell-wall** of cellulose which confers on their bodies a greater amount of firmness and rigidity than in animals As a rule they exhibit very little locomotion, except in some of the Protophyta The vast majority of the higher plants are permanently fixed to the ground which precludes **locomotion.** However, the power of contraction as is seen in primitive animal cells like the body of an Amoeba is present in plant-cells also, which exhibit intrinsic streaming movements of their protoplasm inside the cell-wall

The **nutrition** of both animals and plants is effected by absorption of dissolved food substances, but while animals absorb dissolved organic as well as inorganic matter, plants absorb only inorganic solutions The latter, however, also absorb carbon dioxide, which animals do not In the higher animals there are elaborate arrangements for the capture, injestion and digestion of solid food, requiring the use of several highly specialised organs, while, as a rule, plants which absorb liquids and gases only have no need for such organs. Plants as a rule possess some colouring matter, usually chlorophyll, by the aid of which photosynthesis is effected and the carbon derived from the atmospheric carbondioxide is used for the manufacture of starch. Animals, on the other hand, have no such colouring matter of their own.

The presence of chlorophyll enables plants to derive energy from sunlight, while animals derive energy from the organic substances which they take in as food from plants.

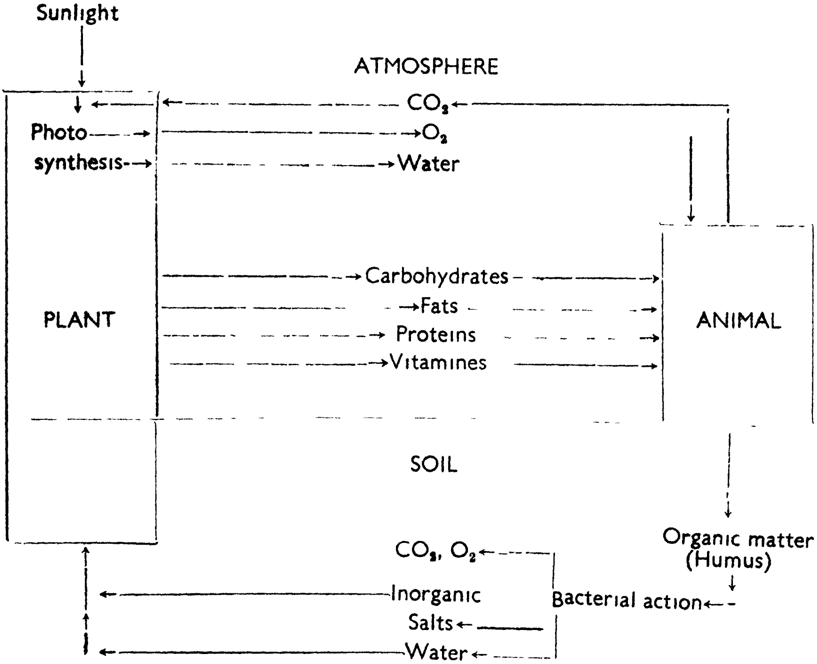
The prevailing **symmetry** among the higher plants is radial, as well as in all the sedentary phyla of animals, e g., the Coelenterata The higher animals differ from plants in that they have developed a bilateral symmetry related to their free-moving habits.

The constant change of surroundings in the case of the free-moving animals has necessitated the development of a **nervous system and sense organs** in them, while in the sedentary plants the power of sensation is, if at all present, only feebly developed

It will be noted that whereas it is quite easy to distinguish one of the higher plants from one of the higher animals, it becomes a matter of considerable difficulty to do so in the case of the lowest plants and animals Till comparatively recently *Obelia* and other zoophytes were mistaken for plants. Among the unicellular organisms (including the Protozoa and Protophyta) there are forms which are, on the one hand, free-swimming like animals and, on the other, provided with chlorophyll and a cellulose skeleton like plants, e g, *Chlamydomonas*, others which are free-swimming and actively food-catching like animals, and at the same time provided with chlorophyll like plants, e g, *Euglena* Such forms which are really plant-animals (Protista) make it impossible to draw a sharp line of demarcation between plants and animals, and bear testimony to the common origin of all living beings

459. The Balance of Nature.—Not only are animals and plants closely related by common origin, but there is a close inter-dependence between the two kingdoms of living beings Animals derive their food directly or indirectly from plants Plants alone manufacture the fats and carbohydrates which form essential parts of the food of animals Even carnivorous animals ultimately depend upon plants, since they feed upon herbivorous prey In turn, plants depend to a very great extent for their food upon animals, whose dead bodies decay and enrich the soil with salts on which plants feed The carbon dioxide breathed out by animals is utilised by plants for the manufacture of carbohydrates by photosynthesis. On the other hand, the oxygen evolved by the plant in this process is useful for the respiration of animals. If we imagine for a moment that there were no plants, it would be seen how helpless animals would have been. As a matter of fact, they could not have come into existence without plants upon which they depend so much for their food and respiration. The dependence of plants on animals, though very real, is not so complete as that of animals on plants, because they derive their sustenance mostly from the soil and energy from the sun. We can reasonably conclude from this that plants preceded animals in the evolution of living beings.

The following chart shows this balance of nature in a graphic manner.



460. The Origin of Life.—We have seen above that living matter is composed of some of the very elements which make up or enter the composition of non-living matter It is therefore reasonable to conclude that living matter has arisen from non-living. How exactly this has come about is not at all known. Formerly it was believed that most of the lower forms of life could and do come into existence from non-living organic matter. This belief was upheld by the supporters of what has been called the theory of **abiogenesis** or spontaneous generation. The appearance of many kinds of micro-organisms and even some worms in putrefying organic matter gave rise to such a belief. Even the embryo inside the uterus was believed to arise spontaneously.

However, in 1680 a certain scientist called Redi proved that maggots could not make their appearance in putrefying meat if flies were carefully excluded from it He also showed that maggots are really hatched out of the eggs of flies. This gave the death-blow to the theory of spontaneous generation Pasteur, the great French scientist, completed the overthrow of the theory by proving that even bacteria could not arise inside a flask, the contents of which were well-boiled and cooled but kept from contamination with air or other matter from outside.

In view of these and similar experiments, which conclusively proved that living beings do not arise from non-living matter, the theory of abiogenesis had to give place to that of **biogenesis** which holds that all life comes from pre existing life only According to this theory, now widely held, all living organisms are born of or produced from living organisms of the same kind by means of eggs, spores, seeds, etc., etc Even such lowly organised forms of life like bacteria can appear in putrefying matter only if their spores are carried into it by air or other agents.

These considerations, however, do not bring us any nearer to the answer to the question, how or when life first came into existence on earth All that we know is that in the present stage of evolution of the earth, life does not appear where none previously was. Who knows but conditions for the formation of living matter from non-living did exist at an earlier stage of the evolution of the earth, or that it would be impossible to imitate those conditions in the future with the advance of knowledge?

REVISION QUESTIONS

375 What do you mean by the terms respiration, oxidation, katabolism, nutrition, assimilation and metabolism?

376 What are the essential properties of living matter?

377. What are the differences between plants and animals? How far can you say that these are absolute?

378. Account for the fact that plants growing very near human dwellings thrive more than others in the same garden What is the health-value of having a garden close to your house?

379 What is each of the following made of timber, bone chitin, gum? What part of each, if any, is made of protoplasm and what part of products of protoplasm?

380. What is the difference between the reproduction of an Amoeba and of an earthworm?

381 What do you think are the reasons for the setting in of senility in Paramoecium? Why are the cells of Histozoa liable to become senile?

382 Explain why tinned butter keeps fresh for a number of days, while home-made butter becomes rancid in a short time? What is the bearing of this on the theory of biogenesis?

383 Make a tabular comparison of the differences between plants and animals

CHAPTER 41

EVOLUTION—VARIATION AND HEREDITY

461. Meaning of the Term Evolution.—Evolution literally means a gradual development or unfolding It has a very wide application as there is hardly a thing that is not subject to a process of development or change All the various mechanical appliances of the present age, e g, the motor car, the typewriter, the sewing machine, the fountain pen, are products of evolution Astronomers hold that the earth on which we live and the Universe itself have slowly evolved. As contrasted with evolution in the inorganic world, evolution in the realm of organic or living beings has been called **organic evolution.**

The theory of (Organic) Evolution holds that the varied forms of living beings which exist on the earth at the present time are the result of a process of gradual development from more lowly organised forms of life which existed in the past Thus, the millions of forms of animal and vegetable life, simple or complex, have all descended from pre existing forms and are mostly different from them in their organisation These changes, according to the theory, have taken an incredibly long period of time, extending into several geological ages, which are perhaps to be computed in millions of years

462. Evidences of Organic Evolution.—There is a vast array of facts from which we can draw in support of the theory of evolution. These facts can be classed into seven groups of biological phenomena

(1) **Relationship between Animals.** Our study of the two vertebrate types, viz, the frog and the rabbit, has shown that these two animals resemble each other in a very remarkable manner, in spite of the several differences between them, both external and internal. Close examination will show that the resemblances are more deep and fundamental than the differences Thus, both these

animals are possessed of a segmented vertebral column and a skull, enclosing the spinal cord and the brain, both have two pairs of limbs and the structure of these in the two resemble very closely; the alimentary canal of the two are fundamentally similar, both in structure and function, their hearts and the blood-systems generally are alike, so much so, that we had to call attention to their differences (Sect 387). There is very great resemblance between the skeletons of the two animals also In fact in almost every aspect of their organisation they show a marked resemblance to each other

The same resemblance would be seen if we compared other Amphibians and Mammals, or indeed for that matter, any other vertebrates

As between the vertebrates and invertebrates also, we note that there is a common plan of organisation Thus comparing the frog with the earthworm, we find the same bilateral symmetry, similar organisation of the body-wall, coelom and alimentary canal, (See Figs 3 and 84, and Sect 286) and the same layers of muscles in the body-wall and gut-wall Going further down the ladder, we note that there is a great and fundamental resemblance between the Histozoa and the Cytozoa in that the bodies of both are made of similar substance, viz, protoplasm, organised into cells Indeed, this character is shared by the vegetable kingdom also, so that all living beings, whether animals or plants, are heirs to this common inheritance

Going back to the rabbit, we find that the wild hare is in almost all respects, except colour and a few other traits, very similar to it, so that we do not hesitate to speak of the two animals as *being related* In other words, we make out a family likeness between these two species of animals—a likeness similar to that between two brothers or cousins We have no hesitation in attributing family likeness to a common inheritance or parentage If close resemblance like that between two brothers or cousins is a mark of common parentage or inheritance, it follows that the similarities that run through the Vertebrates are a proof of their common origin from a remote ancestor. In the same way the resemblances that run through the entire organic world point to a still more remote, but common, ancestry for all living beings.

(2) **Progressive Structural Modification.** Our study, though confined to but few types, has shown clearly that animals as we find

them at the present day show a progressive modification of structure from the Protozoa or Cytozoa to the highest Histozoa. In Protozoa we find single cells as individuals. In the Coelenterata, cells are organised into two simple layers, the ectoderm and endoderm, accompanied by a certain amount of division of labour between these two layers, as well as the formation of a digestive cavity or coelenteron associated with the nutrition of the organism. In the flatworms a third layer is added, viz., the mesoderm and in the Annelida a coelom is formed in that layer. Passing on to the Vertebrata, we note that the triploblastic and coelomate conditions persist, but other fundamental structural features like an internal skeleton, a notochord, brain, etc , are added. These facts are more clearly understood from the following table

TABLE 19

PHYLA GRADED ACCORDING TO ORGANISATION

PHYLUM	NEW CHARACTERS ADDED
Protozoa (Solitary) ↓	Protoplasm organised into motile cell
Protozoa (Colonial) ↓	Products of cell-division keep together, organically connected, working for common welfare Spheroidal symmetry
Coelenterata ↓	Association of cells organised into two cell-layers or epithelia, viz , ectoderm and endoderm Division of labour among tissues begun Gut cavity formed Primary axis established Diffuse nervous system Radial symmetry
Platyhelminthes ↓	Third germinal layer or mesoderm formed Division of labour among organs established Well defined nervous system, feeble sense organs Excretory tubules formed Bilateral symmetry
Annelida ↓	Metamerism, with several paired, unjointed appendages Coelom formed in the mesoderm Vascular system with blood-vessels
Vertebrata	Gill-slits opening out from mouth Notochord, Vertebral column Internal skeleton Chambered heart Well developed brain and sense organs Two pairs of jointed appendages

(3) **Embryonic and Larval Development.** Table 19 shows the progress of the animal kingdom from the more lowly organised to the more highly organised phyla as we find them on the face of the earth at the present time This can be called **phylogeny** as against **ontogeny** or the progress of the individual from the single-celled zygote to the adult condition The ontogeny of a *vertebrate animal* affords a striking parallel to the phylogeny of the *Vertebrata* Beginning with the zygote, the embryo passes through stages which are highly reminiscent of the various phyla that come in between the Protozoa and the Vertebrata Taking the example of the frog, an account of whose development has already been studied, we note that a frog starts on its individual existence from the moment of fertilisation of the ovum by a sperm resulting in a zygote The zygote passes into a blastula, gastrula, triploblastic embryo, embryo with mesoblastic somites and coelom, embryo with notochord, nerve cord, brain and sense organs, larva with gill-slits and chambered heart, and finally into the adult with two pairs of limbs Here then we have a clear illustration of the biological teaching that *in the ontogeny of the individual the phylogeny of the race is recapitulated.* The close parallelism between ontogeny and phylogeny of the frog is seen at a glance from Table 20, which should be compared with Table 19.

TABLE 20

ONTOGENY AND PHYLOGENY OF THE FROG

ONTOGENY	PHYLOGENY
Zygote or single cell stage	Protozoa (Solitary)
Blastula, hollow sphere of cells, spheroidal symmetry	Protozoa (Colonial)
Gastrula, diploblastic stage, with two layers of cells, with a gut cavity, primary axis, and radial symmetry	Coelenterata
Embryo with mesoderm and bilateral symmetry	Platyhelminthes
Embryo with mesoblastic somites (metameric), coelom and blood	Annelida
Larva with gill-slits, notochord, vertebral column, internal skeleton, chambered heart, brain, and sense organs	Fish
Adult with two pairs of limbs	Amphibia

Now, we know that all the structural features of an animal have been inherited by it from its ancestors. Evidently, not only the adult characters, but also, those of the larva, embryo, and zygote are features that have been thus inherited. If the adult features have been inherited from the Amphibian (frog), the fish-like characters of the tadpole must have been inherited from a fish-like ancestor, and those of the zygote from a single-celled, Protozoa-like ancestor.

We know that certain animals are more allied to each other anatomically than others Thus the members of the cat-family, viz, the lion, tiger, leopard, cat, etc., resemble each other much more closely than any of them resembles a dog. These anatomical resemblances are most marked among animals whose developmental stages also resemble each other very closely. When we study the ontogeny of a number of closely allied forms, like the cats, we find that the peculiar characters of the adult of each species make their appearance in the respective embryos only towards the end of development, while in the earlier stages they are practically indistinguishable from each other. The only explanation we can give to this is that all of them have inherited these common features from a common ancestor, the specific characters which distinguish them from each other having been added later in the descent of each species

(4) **Fossil Record.** The crust of the earth contains innumerable remains of animals and plants that lived in the remote past. It is known that the crust has taken millions of years to form, and generally speaking, the deeper the crust the more ancient it is The animal (and plant) remains found in the deeper layers will be correspondingly older, and those in the more superficial ones, more recent. The crust of the earth has been divided into four main layers. These are from the oldest to the most recent in order, the Palaeozoic or Primary, the Mesozoic or Secondary, the Cainozoic or Tertiary and the Recent or Quarternary. Table 21 shows these geological strata with the epochs into which each is divided, and the animal groups found in each

TABLE 21

RANGE OF ANIMAL GROUPS IN THE CRUST OF THE EARTH

CRUST OF EARTH			RANGE OF ANIMAL GROUPS					
ERAS	EPOCHS	THICKNESS IN FEET	Invertebrates	Fishes	Amphibians	Reptiles	Birds	Mammals
Quarternary	Recent and Pleistocene	4000						
Cainozoic or Tertiary	Pliocene	13000						
	Miocene	14000						
	Oligocene	12000						
	Eocene	20000						
Mesozoic or Secondary	Cretaceous	44000						
	Jurassic	8000						
	Triassic	17000						
Palaeozoic or Primary	Permian	12000						
	Carboniferous	29000						
	Devonian	22000						
	Silurian	15000						
	Ordovician	17000						
	Cambrian	26000						
	Precambrian	Unknown						

It will be seen from the table that invertebrates appear first and vertebrates later and that among the vertebrates the fishes are first, while birds and mammals are last These facts are in complete accord with the theory of evolution, according to which the more primitive organisms precede in time the more advanced ones.

Palaeontology also affords some instances of evolution of a particular type of organ, for example, the single toed foot of the horse and the shortened head and elongated tusks of the elephant. A series of fossil horses and elephants are known which show the progressive development of these peculiar organs from perfectly normal types now extinct.

(5) **Vestigial Structures.** In many living organisms we see

apparently functionless vestigial structures, which in other forms are well developed and functional These may be present throughout life or may last only for a time Examples of vestigial structures are numerous, e g , the vermiform appendix and coccyx (tail vertebrae fused) in man, limb bones in certain snakes like the Python, third eyelid in mammals, toes of the human foot, human external ears, etc , etc The presence of these vestigial structures becomes altogether inexplicable unless they point to a common descent of their possessors with forms which possess them in a well developed condition Sometimes, these vestigial organs may be positively harmful, e. g., the vermiform appendix in man, and their tenacious persistence can be due only to their remote ancestors having possessed them in a well developed and functional condition.

(6) **Persistence of Fundamental Structure in spite of widely differing Adaptive Modifications.** The higher vertebrates are all typically pentadactyl, but we see in them adaptations for aquatic, terrestrial, arboreal or aerial life, as the case may be The use to which the limbs are put by the animals living in different media is different. At the same time a close examination of the structure of these limbs shows clearly that the human hand, the horse's foot, the bird's wing, the bat's wing, the flipper of the whale, are all built on the same fundamental plan These resemblances between organs so widely different in use are absolutely meaningless, unless they indicate a common origin

(7) **Domesticability.** It has been possible for man to domesticate many animals and plants The dog, horse, cow, pigeon, fowl, etc , among animals, roses, peas, wheat, paddy, etc , among plants are examples. In each of these, out of the same original wild species, man has produced an infinite variety of forms, sometimes so different from each other, as to be mistaken for separate species This shows that species are not immutable, but are capable of change If, therefore, such changes can take place under domestication, there is no reason why similar changes should not take place in wild nature

463. The Method of Evolution.--There has been much speculation about the way in which Evolution has been working out the modification of species, resulting in the formation of new ones, The theories advanced by Lamarck (1809), Darwin (1859), and Hugo de Vries (1886) in this connection may be briefly considered.

464 Lamarck's Theory of the Inheritance of Acquired Characters.—Lamarck believed that the environment had a profound influence upon the individual, and as the environment changed the animals also found it necessary to change so as to adapt themselves to the new environment By environment is meant, factors like climate, food, enemies, habitat or medium, etc When a change in environment took place, the animal had to put forth a special effort of some of its organs in order to meet the situation The extra use to which the organ is put tends to modify that organ, in the same way hard muscular exercise tends to strengthen the muscles Conversely disuse of any organs would tend towards inefficiency and gradual atrophy of the organ concerned During the life time of an individual its body would thus be altered to a certain extent as the result of environment and the efforts induced by the environment in its organs In other words it *acquires* certain characters These acquired characters are transmitted by heredity to the progeny, which consequently is better equipped to live in the changed environment than its parents

According to Lamarck, the remarkable stature and length of neck of the giraffe is the result of such inheritance of acquired characters through several generations The giraffe lives in the arid planes of the interior of Africa The animal has, therefore, to browse upon the foliage of trees As the leaves at the bottom are finished off, the animals have to reach further and further to the top of the trees, for which they have to stretch their necks and fore-limbs continuously Such continual effort by all the members of the species over a long period has, according to Lamarck, resulted in the peculiar adaptations of the species[1]

465. Darwin's Theory of Natural Selection.—It is well-known that in most animals and plants, a very large number of eggs or seeds are produced, so that if all the progeny were to survive, the number of individuals of each species would be multiplied several times in the course of a single season But in nature, this does not happen We do not see any extraordinary increase in numbers of any species except very occasionally, as, for example, in the case of locusts.

This means that the vast majority of the offspring are destroyed, since the available food, shelter and other necessaries would hardly be sufficient for such large numbers. On the other hand, if the offspring of a single individual did all manage to survive without any casualty for a few generations, they would soon inundate the entire surface of the earth. For example, it has been calculated that if the progeny of a single oyster survived and multiplied till the 5th generation, the heap of shells would be eight times the size of the earth Or again, if the progeny of a single Paramoecium were all to survive and reproduce for five years, the mass of protoplasm thus produced would be ten-thousand times the volume of the earth. In spite of such prodigious capacity for reproduction there is no increase in the number of the individuals of any species. The balance of nature is kept up, by what Darwin has termed the **struggle for existence,** or the competition between members of the same species for food, space, etc. (intraspecific struggle) or between members of different species (interspecific struggle) or against the inclemencies of the environment (environmental struggle) In this struggle not all competitors have, according to Darwin, an equal chance of survival, but only those which are more fitted in virtue of their particular favourable **variation.** Now by variation is meant the divergences of all kind between the individuals of a species These are of universal occurrence as is clearly seen from the fact that no two individuals of a species are absolutely identical. There will always be some differences, however minute, between them Some of these variations may tell in the struggle for existence and enable their possessors to survive their fellow-competitors in the struggle For example, in a herd of wild deer pursued by a tiger or other predacious enemy, those that are swifter of foot may have a better chance of escape than the others In other words, those only that are fit to survive are allowed to survive. Thus in the struggle for existence, variations bring about the **survival of the fittest.** Now variations are inheritable (unlike acquired characters, whose inheritability has been seriously called in question) and in the course of generations these become fixed characters of the species If there is change in environment, the individuals selected will be those that are most fitted in virtue of their favourable variations to survive in the changed conditions. The influence of this selective process long continued will result in **structural modifica-**

tions, so that in course of time a new species arises as a modification of a pre-existing one. If now the environment remains stationary, the new species is perfected for life in that environment

466. De Vries' Theory of Mutation.—By mutation is meant a sudden marked change appearing in the offspring of normal parents, as contrasted with the minute or inconspicuous variations in degree to which the name fluctuating variations has been given For example, in America a ram was born with extremely short, stumpy legs, of quite normal parents. This was taken advantage of by the owner who raised a whole flock of short-legged sheep from this single ram as sire. In other words, a new variety of sheep, to which the name Ancorn sheep was given, had sprung up in the course of a few years. According to De Vries, it is such marked variations or mutations that are taken advantage of by nature for the creation of new species and not the slight or fluctuating variations which, Darwin said, were the basis of species-formation

467. Variation—Physical and mental similarity between parents and offspring or between offspring of the same parents is a matter of common observation But, however close these resemblances, they are never absolute or complete Even in the so-called identical twins there are points of dissimilarity along with the more obvious points of similarity, so that in a real sense we may say that no two organisms, however much they resemble each other, are ever altogether alike.

These dissimilarities which enable us to distinguish one member of a species from another may be spoken of as variations which are of universal occurrence in the organic world Examples are very numerous:—Man and Mammals—colour of skin, eye, etc , hairiness of the body, height, weight, face-cut, number of digits, lines on the palm, intelligence, etc. Plants—height, branching, colour of flower, number of petals, sepals, etc., number of leaflets, size of leaf, margin, venation, etc., etc.

468. Classification of Variations.—Variations can be classified from the point of view of their nature, extent or origin and in each case brought under two contrasted headings :

(1) **Nature**—whether the variation is exhibited in a numerical increase of parts, or whether it has to do with the size, weight,

material, shape, colour, etc., of the organism or a part of it. Thus we have **meristic** or numerical variations, contrasted with which are **substantive** varations or variations in the substance of which the organism or a part of it is made. Taking the case of hexadactyly in man, it will at once be seen to be a meristic variation since there is an increase in number of the fingers from five to six.

(2) **Extent**—whether the variation is only a slight change from the normal of the species or whether it is a marked change of infrequent occurrence and without any relation to the normal of the species Thus we have **fluctuating or continuous** variations of a positive or negative kind contrasted with discontinuous variations or **mutations** of a positive or negative kind. From this point of view, hexadactyly will be a mutation and not a fluctuating variation.

(3) **Origin**—whether the variation is due to the innate quality of the germ cell from which the organism arose, i e., whether it is an inborn quality, or whether it has arisen from the effect of the environment upon the organism in any stage of its existence Thus we have **blastogenic** variations contrasted with **somatogenic** ones. Hexadactyly is evidently of the blastogenic type, since it is an inborn and not an acquired character

469. Variation and Evolution.—Heredity tends to make one generation resemble its predecessor. If heredity without variation were operating, there could be no adaptations or Evolution. If the restraint of heredity is removed, on the other hand, then variations alone would operate and there would occur an organic revolution. Thus variation and heredity, although apparently opposite forces, supplement each other and the two operating together result in Evolution. Heredity and variation are, thus, not really opposing forces, but different phases of the phenomenon of inheritance.

It is disputed whether somatogenic variations contribute at all towards evolution since they are not known to be inheritable. Hence the weakness of Lamarck's theory of the Inheritance of Acquired characters On the other hand Darwin's Theory of Natural Selection makes use of fluctuating variations which are certainly inheritable. De Vries bases his theory on mutations or discontinuous variations which are also inheritable.

470. Causes of Variation.—There is great diversity of opinion as to the causes of variation, and little is known with definiteness. Somatogenic or acquired variations are definitely tracable to the environment. These may be environmental or extrinsic, brought about by food, temperature and other conditions in the environment of the organism, or intrinsic or physiological, due to the use or disuse of parts or organs of the body

The origin of blastogenic variations is more difficult to understand, as these are necessarily concerned with the germ-cells, and depend on their innate qualities Weismann finds in the mixing of two strains in fertilization (amphimixis) one of the causes of blastogenic variation The germ-cell is a very complex body containing the material representatives of every conceivable character of the species. The germ-cells, we may presume, will differ among themselves as the parents from whom they are derived, and the resulting organism is likely to show a mixture of characters of the two parents and therefore different from both This view, it will be seen, is corroborated by Mendelism

471. Effect of Environment on the Germ-Cell.—Does the environment affect the germ-cell as it affects the body, so as to produce variations in the progeny? Weismann answers this question in the negative but there is no reason to believe that the germ-cells (germ-plasm) in this connection is different from the body-cells (somatoplasm) which are evidently affected by the environment The hereditary adaptations met with among animals, e g, the loss of pigment in *Amblyopsis*, a cave-dwelling fish, or the loss or atrophy of eyes in the burrowing Coecilians (Gymnophiona) can ultimately be attributed only to the environment There may be no effect on the germ-cell in a few generations, and in so far as that is true, the germ-cell may be said to be stable as Weismann contends, though there may be a cumulative effect of generations which ultimately results in the fixation of the character in question as a hereditary one

The American Scientist, Tower, studied the bettle *Leptinotarsa* in this connection. In nature he found 1/6000 of these bettles' are mutants, in captivity mutations were more frequent, while, when the full-grown insects are subjected to extremes of temperature, humidity, etc, 80% are mutants and the mutations breed true, though the parents were not visibly affected by the abnormal conditions, But obviously the ova were affected. The ova derived from the same parents, afterwards under normal conditions, gave rise to normal individuals. This experiment clearly shows that environment can change the nature of the germ-cells which, however, need not mean that the germ cell is affected by every kind of environmental change

Weismann cut the tails of mice, derived from the same original pair, for a number of generations without in any way affecting the nature or size of the tails in the offspring It is clear that mere mutilations are not inheritable.

472. The Hereditary Bridge.—As the germ cells, male and female are the only connecting links between two consecutive generations, it is evident that they are the material bodies through which the hereditary characters pass from one generation to the next. The zygote has in itself all the hereditary possibilities of the adult In the Protozoa the parents divide into two daughter-individuals, and that the daughters should possess the characteristics of the mother is just what we should expect. In the multicellular animals, on the other hand, only an infinitely small portion of the parent forms the germ-cell , and how all the hereditary characters of the parent are, so to say, locked up within the small compass of the germ-cell is the problem we have to tackle

The most hopeful method of unravelling the mysteries of heredity in the Metozoa would therefore seem to lie in the study of the germ-cell which has been called the carrier of heredity, the physical basis of heredity, the hereditary.bridge, etc

473. The Hereditary Value of the Sexes.—From the fact that the ovum is larger than the sperm and also that in many animals the earlier part of the development takes place inside the mother, receiving nourishment from her, it has been argued that the female contributes more towards the hereditary characters than the male.

But we see that · (1) Paternal and maternal charcters are more or less equally divided in the young. (2) When reciprocal crosses are made between two closely allied species as the horse and the donkey the result is always a mule, i e , an hybrid different from both parents, and it makes no difference whether the horse is the sire or the donkey. Hence it is clear that the contribution made by the two parents towards the inheritance of the young is equal in extent though not necessarily similar in nature

474. The Seat of Heredity in the Germ-Cell.—(1) The tail of the sperm is shed in fertilisation, and the head alone, that is the nucleus, enters into the formation of the zygote. This seems to indicate that the nucleus alone is important as a carrier of hereditary characters. (2) In the maturation divisions of the germ-cells which take place immediately before fertilisation, it is the nucleus that undergoes elaborate processes of preparation, the protoplasm remaining almost quiescent. This also points to the conclusion that the nucleus is more concerned with heredity than the protoplasm. (3) The chromosomes in the germ-cells are invariably half the number characteristic of the species , and the circumstance that in fertilisation the number is restored to the normal of the species is in agreement with the young inheriting its characters, on an average, half and half from the two parents If so the chromosomes must be the bearers of heredity (4) In the conjugation of some Protozoa nuclear matter alone is exchanged (5) Boveri's experiment on the eggs of sea urchins in which he shook out the nucleus from the eggs of *Sphaerechinus* and fertilised the enucleated ova with the sperms of *Echinus* resulted in the development of *Echinus*-larvae only This shows clearly that the nucleus is the more important part of the germ-cell as far as heredity is concerned

475. The Mechanism of Heredity.—Several attempts have been made to explain the mechanism by which the germ cells come to represent the hereditary potentialities of the parents The only satisfactory answer to the problem is that of Weismann, viz , his theory of the **Continuity of Germ-Plasm,** which is based on a firm basis of experiment and observation, viz :— (1) If the germ-producing organ in animals, i e , the gonad, is removed, complete sterility results, no matter how early in the life of the individual This means that no other part of the body has the inherent capacity to give rise to germ-plasm or germ-substance. (2) In many animals that have been studied, e. g., the round-worm *Ascaris megalocephala* (See Sect. 253) one of the blastomeres of the early stages of development is seen invariably to be set apart for the formation of the primitive sex cells which ultimately become localised in the gonads, The main postulates of the theory are (1) There is a distinction between the germ-cells made of germ-plasm and the body-cells (all cells except the germ-cells) made of somatoplasm. (2) The germ-plasm is segregated in the early stages of development from the rest of the body (3) The germ-plasm gives rise by division and growth to all the germ-cells of the organism, which are able to give rise to a new generation, whereas the somatoplasm can give rise only to the cells of the body which sooner or later die and lead to nothing Thus the germ-plasm of the germ-cells is capable of giving rise to all the cells of the body including the germ-cells and the body-cells. (4) The germ-cells of an organism thus consists of a portion of the original germ-plasm of the cell from which it arose (only grown by absorption of nutriment), so that there is a continuous and unbroken stream of germ-plasm running through the generations (continuity of germ-plasm). (5) The body is, as far the germ-cells are concerned merely a temporary lodge for the germ-plasm, where it grows and divides. (6) That there is a hereditary likeness between the generations is thus due to the fact that both arise from the same stock of germ-plasm, only the development takes place at different times, one after the other.

Weismann also believed that the germ-plasm cannot be modified by environmental factors Thus acquired characters cannot leave their impress upon the germ-plasm, and cannot therefore be inherited This however is very questionable It is true that no mechanism by which the influence of environment on the soma resulting in its modification can be impressed upon the germ-plasm has yet been discovered But this is not the same as saying that there is no such mechanism

476 Kinds of Inheritance.—From the nature of their appearance in the organism we can speak of the hereditary characters as blending, particulate or alternate

Paternal and maternal characters, so to say, mix with each other in the offspring ; e g , human height in which the offspring may be graded ; coat-colour, a white mouse crossed with a black mouse may give rise to a grey-brown offspring. This is called **blending** inheritance. When the characters of the two parents do not mix in the offspring, but both make their appearance side by side as when a white mouse and a black mouse give rise to piebald offspring, we speak of it as **particulate.** When the paternal or maternal character alone makes it appearance in the offspring, as when a white and a black mouse produce an all-black offspring, we speak of **alternating** inheritance

477. Laws of Inheritance.—There are different methods of studying variations and heredity Darwin's method was to collect isolated examples of variation and make deductions therefrom Galton based his studies on statistical data, derived by measuring the amount of variation of one kind or another in a large number of cases, whatever the kind of variation, and forming conclusions from the tabulated data Mendel's method was to investigate the inheritance of separate characters (unit characters) by breeding experiments As the result of these certain laws have been formulated, but there is no complete agreement between the laws enunciated by the various workers in the field Chief among these are Galton's laws and Mendel's laws

478. Galton's Law of Variation.—Fluctuating variations lend themselves most readily for statistical analysis, the characters concerned being subject to actual measurement in most cases. Galton has enunciated the following law from his statistical studies "The number of individuals exhibiting any given degree of variation from the mode (average) of the species is inversely proportional to the amount of that variation" In other words, the larger the variation, the fewer the number of individuals that posses it

479. Galton's Law of Inheritance.—"The two parents between them contribute an average of one half of the total heritage of the offspring , the four grand parents ¼ , the eight great grand parents 1/8 and so on , the sum of the ancestral contribution to heredity being $1/2+1/4+1/8+1/16+1/32\ldots\ldots = 1$. It will be noted that this law clearly envisages the possibility of characters being inherited, not only from the immediate, but also from the more remote ancestors.

480. Galton's Law of Filial Regression.—The offspring of parents exhibiting a marked deviation from the average of the species would tend to inherit that deviation to a lesser degree (1/3 of the parental deviation) than was present in the parents. The influence of the remote ancestry tends to counteract that of the parents and causes a partial return or regression towards mediocrity. The children of geniuses are not always geniuses, but they may be on an average a bit more brainy than the children of average people. The grand children will be just normal and in the course of a few generations the progeny will have lost that character altogether. So with dullness, stature or ony other character. This is illustrated by the following tabular statement in which variation in human stature basad on actual measurement of 204 parents and 928 offspring is the subject of study.

HUMAN STATURE CHART TO SHOW FILIAL REGRESSION

Midparent* Height	64 5	65 5	66 5	67 5	68 5	69 5	70 5	71 5	72 5
Average Height of Offspring	65 8	66 7	67 2	67 6	68 3	68 9	69 5	69 9	70 3

The social or eugenic importance of the law is expressed by Karl Pearson in the following words "It is the heavy weight of this mediocre ancestry which causes the son of an exceptional father to regress towards the general population mean , it is the balance of this sturdy commonplaceness which enables the son of a degenerate father to escape the whole burden of the parental ill Among mankind we must trust largely for our exceptional men to extreme variations occurring among the commonplace, but if we could remove the drag of the mediocre element in ancestry, were it only for a few generations, we would sensibly eliminate regression or create a stock of exceptional men "

481. Mendelism.—The first exponent of the experimental method of attacking the problems of heredity with a view to finding out the laws that govern inheritance was Gregor Johann Mendel, an Austrian Monk who published an account of his work as early as 1865, the importance of which, however, was not recognised by the scientific world till 1900 In his experiments, Mendel realised the importance of (1) looking at the germ-cell as the carrier of hereditary characters and making that the point of attack and (2) of fixing attention on separate or unit-characters as against viewing the organism as an indivisible whole.

482. Mendel's Experiments on the Garden Pea.—Mendel chose two different varieties of the garden pea, a tall variety 6 to 7 feet and a dwarf variety ¾ to 1½ feet, that are generally found growing mixed in most gardens, and crossed them by artificial cross-pollination in large numbers, keeping an accurate record of all that he did. It was necessary to prevent self-fertilisation in order to ensure that all the seedlings of the next generation were hybrids. All the seeds resulting from the cross-pollination were carefully collected and sown When the seedlings grew up they were not a mixture of talls and dwarfs as was expected, *but all were talls.*

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*Mid parent height $= \frac{1\ 00 \text{ male height} + 1\ 08 \text{ female height}}{2}$, male height being 1 08 female height.

When the plants flowered, they were protected against cross-fertilisation and were artificially self-pollinated each plant by its own pollen The resulting seeds were all carefully collected and sown As the result of this a generation of plants arose which were a mixture of talls and dwarfs This was not surprising as half the grand-parents were tall and half dwarf, but what was surprising was that when the plants were sorted and counted, it was found that there were thrice as many talls as dwarfs, the ratio 3 1 being astonishingly fairly correct

In the next stage of the experiment, Mendel self-pollinated the plants as before and the result of the subsequent sowing was as follows

1/3 of the talls produced talls, 2/3 of the talls produced a mixture of talls and dwarfs in the proportion of 3 tall 1 dwarf, and the dwarfs produced only dwarfs.

The self-fertilisation and breeding were carried out again and it was found that the talls, which gave rise to talls only, continued every time to breed true, that is, give rise to talls only, and the dwarfs also behaved similarly, i e, gave rise to dwarfs only The remaining talls, however, continued to produce a mixture in the same proportion as before at every successive breeding, resulting in the elimination of a pure tall strain and a pure dwarf strain.

483. Mendelian Formulæ and Terminology.—For the sake of clearness and brevity, what was described above may be expressed in the following formula —

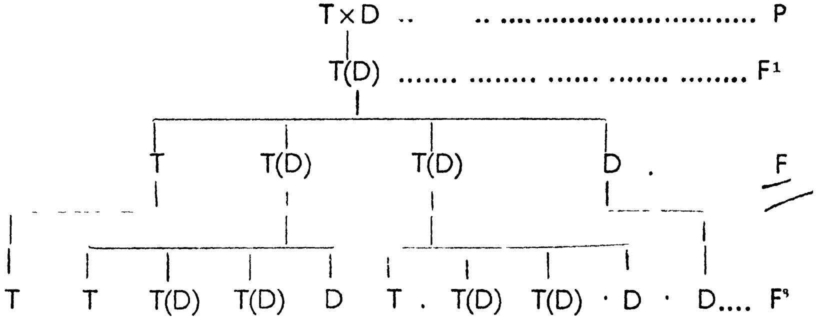
$$\begin{array}{ccc} T \times D & \qquad & \ldots\ldots P \\ | & & \\ T & & F^1 \end{array}$$

where T represents Tall, D dwarf, × the crossing between the two, P the original parent generation and F^1 the first filial generation

T of F^1 is however known to be a hybrid, and this fact is expressed as follows —

$$\begin{array}{ccc} T \times D & \qquad & P \\ | & & \\ T(D) & & F^1 \end{array}$$

The whole series of experiments may be written as follows:—

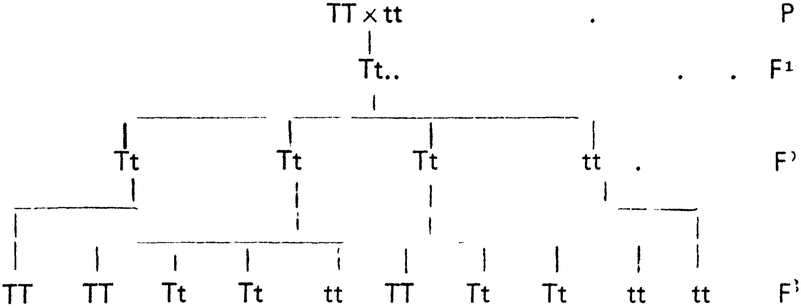


Since dwarfness never makes its appearance in the F¹ generation even though it is undoubtedly a hybrid, its presence is supposed to be inhibited by tallness This is expressed by saying that Tall is **dominant** over Dwarf which is **recessive.** Dwarfness is obviously the absence or want of tallness, and these two characters form a contrasted pair or **allelomorphs.** Each organism was considered by Mendel to be a composite of a number of independent characters like tallness of stem or yellowness of seed-coat, the absence of which will lead to dwarfness or greenness respectively. Such characters are called **unit characters.** Mendel's credit lies in appreciating this idea for the first time

While T(D) is a hybrid plant, TT and DD are pure varieties as far as height is concerned and are respectively called **extracted dominant** and **extracted recessive** which breed true in all subsequent generations raised by self-pollination A zygote having similar factors for any character, e g , TT or DD is called a **homozygote,** while a zygote combining both the opposite factors of the allelomorphic pair, viz , T(D) is known as a **heterozygote.**

484 The Germ-Cell and the Zygote.—Since the zygote and therefore the adult results from the union of two germ-cells carrying like or unlike factors for any character, the zygote contains a double-dose, as it were, of factors whereas the germ-cell contains only a single doze In other words, while the germ-cell is either T or D only, the zygote and the adult are TT or TD or DD. If we presume that dwarfness if the absence of tallness, we can express the presence and absence of tallness in the two plants of the original parent generation by saying that the tall plant is TT, the dwarf tt and the hybrid of the F^1 generation Tt, where T stands for Tallness and t for its absence

Accordingly the formula may be rewritten —



485. Explanation of the Proportion 1 : 3 in F .— Mendel's experiments in hybridisation are really experiments with pollen-grains and ovules ; in other words with germ cells, whether of plants or of animals It has been seen (Sect 473) that the hereditary value of the male and female are equal so that there is no need for us to consider them separately as ovules or pollen-grains and as ova or sperms. For the success of the experiment pollination with T- or with t-pollen will do equally well Thus supposing that 100 pollen-grains of a T-plant fertilised 100 ovules of a t-plant or *vice versa*, we would get 100 seeds all of one kind, viz , Tt of F^1

The plants of the F^1 generation can give rise to germ-cells of two kinds, viz , T and t, in equal numbers When a plant is self-pollinated, the zygotes will by the law of chances be formed as follows:

T t
T t

TT Tt
Tt tt

1TT 2Tt 1tt

That the germ cells would unite in fertilisation in the manner aforesaid can be illustrated also by the following experiment.

Procure a handful of grains of rice or other cereal and colour half of them, say, red, and the other half blue Count out 100 of each colour and mix them up well in a small tin or other con-

Experiment

tainer. Let one of the students be blind-folded and let him sort out the grains two by two and place them on the table, while three others arrange the red pairs, the blue pairs and the red-and-blue pairs separately in different parts of the table When all the 100 pairs have been properly allocated to their respective places on the table count each of the three groups. It will then be seen that there are very nearly, if not exactly, 25 red pairs, 25 blue pairs and 50 red-and-blue pairs

From this and similar studies in hybridisation, three general principles of heredity, which we may call **Mendel's Laws,** stand out clearly. These are the Law of Dominance, the Law of Segregation and the Law of Unit Characters

486. The Law of Dominance.—When two parent types differing from each other with reference to a single unit character are crossed the hybrid-character resembles that of one of the parents very closely or indeed may appear to be identical with it. This law is clearly illustrated by the F^1 generation of the hybridisation experiment described above (Sect 482) in which the dominant T-factor has entirely suppressed the recessive t-factor The Law of Dominance, however, is not applicable in all cases, for there are several instances known where dominance is either incomplete or entirely absent

487. The Law of Segregation or Purity of the Gametes.—We have seen above (Sect 474), that there is reason to believe that the chromosomes are the carriers of hereditary characters and in the maturation of the germ-cells, it is noted that they undergo profound changes the result of which is to reduce the number of their chromosomes to half of that of the gametogonium and of the cells of the soma. Suppose there are four chromosomes, I, J, **I** and **J** in any gametogonium (Fig. 47) These four are in virtue of the mitotic divisions by which they were produced, direct descendants of the four chromosomes of the oosperm or zygote from which the individual arose, and are therefore derived in equal proportion from the two parents Let us imagine that chromosomes I and J come from the father and **I** and **J** from the mother. In the primary gametocyte, it is seen that I and **I** come together in synapsis as also J and **J**, and the four germ-cells that result contain these as follows ½**I**.½J, ½I.½**J**, ½**I**.½**J**, ½I ½J (See Fig. 47, B). In other words each germ-cell carries with respect to any one particular hereditary character, chromatin from one parent only and not from both. Thus the F^1 generation peas would give rise to germ-cells which carry the factor for tallness (T) of the one parent or the factor for dwarfness (t) of the other, and not both T and t.

From this we conclude that in the process of maturation, there is what is called **segregation** of factors for hereditary characters. In other words, each germ cell is pure with respect to any particular character, containing, as it does, only one or the other of the two factors forming an allelomorphic pair, unlike the zygote which will contain two factors for each character derived from the two parents, being either homozygous or heterozygous ✓

If segregation actually took place as indicated above, each germ-cell will be either T or t with regard to the character tallness, and these should be produced in equal numbers when derived from the F^1 hybrid plant

The importance of this law from the point of view of breeders and its bearing upon problems of eugenics will at once be appreciated ; for even a hybrid is capable of giving rise to pure germ-cells and if crossed with a pure strain would produce progeny of which half at least would be extracted pure

488. The Law of Unit Characters.—In the experiment cited above (Sect 482) Mendel fixed his attention on a single hereditary feature or unit character Every organism is made up of a large number of such characters, the inheritance of each of which is independent of the presence or absence of the other characters, excepting that when the same chromosome contains the factors (genes) for more than one character, they would be linked together and therefore make their appearance as a group of unit-characters in the offspring.

489. Monohybridism and Dihybridism.—Mendel's experiment in breeding above cited is one in which only a single pair of alternative characters or allelomorphs are taken into consideration, and illustrates, what in Mendelian terminology is called, monohybridism.

But when two allelomorphic pairs are taken into consideration in the same breeding, it is called dihybridism For example, we can choose for experiment one plant which has round green seeds and another which has wrinkled yellow seeds, and cross the two. In peas such varieties do occur, and from independent experiment we know that yellow is dominant over green which is recessive, and round is dominant over wrinkled which is recessive. The two plants will then be represented thus —

Round green seeds RG ; Wrinkled Yellow seeds. WY

When these are crossed, the F¹ generation is a hybrid having the constitution RY(W)(G), so that the plants raised from this crossing are all, as far as appearance goes, RY When the F¹ generation is inbred the progeny, i e, the F² generation, is in the following proportion

3RG . 9RY 3WY . 1WG

The whole experiment may be thus represented

RG × WY ... .. P
RY(W)(G) . .. . F¹
3RG . 9RY 3WY . 1WG .... F²

This result is explained as follows —Plant RY (W) (G) of the F¹ can produce the following kinds of germ cells RG, RY, WG, WY, so that in fertilisation the following combinations take place —

	RY	WG	WY					
	RY	WG	WY					
G	RRY(G)	R(W)GG	R(W)Y(G)					
	RRY(G)		R(W)Y(G)	RRYY	R(W)YY			
		R(W)GG	R(W)Y(G)			WWGG	WWY(G)	
			R(W)Y(G)		R(W)YY		WWY(G)	WWY
G	2RRY(G)	2R(W)GG	4R(W)Y(G)	1RRYY	2R(W)YY	1WWGG	2WWY(G)	1WWY

Since W and G are recessives these will not make their appearance when in combination with the respective dominant factor, the plants will actually have the appearance as follows —

1RG 2RY 2RG 4RY 1RY 2RY 1WG 2WY 1WY, that is, 3RG 9RY 3WY 1WG.

The same result will be obtained by working out on a chequerboard as follows.—

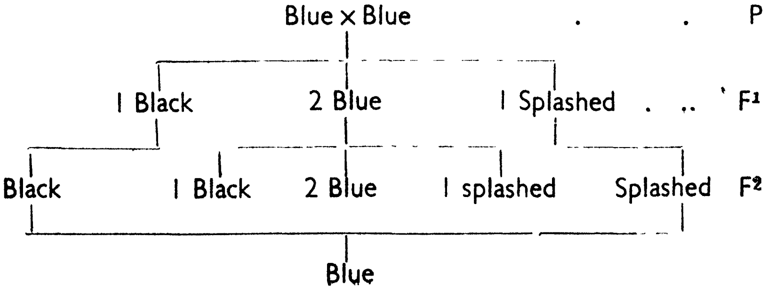
Pollen Grains

Ovules	RG	RY	WG	WY
RG	RG RG	RY R(G)	(W)G RG	(W)Y R(G)
RY	R(G) RY	RY RY	(W)(G) RY	(W)Y RY
WG	RG (W)G	RY (W)(G)	WG WG	WY W(G)
WY	R(G) (W)Y	RY (W)Y	W(G) WY	WY WY

=9 RY+3 RG+3 WY+1 WG

490. Trihybridism.—In a similar manner three unit characters may be taken into consideration in the same breeding experiment. The F^1 plants will produce 2^8, i e, 8 different kinds of germ-cells and the result can be worked out on a chequer-board with 8×8=64 columns—and so on

491. Inheritance in Animals.—Inheritance in Mendelian fashion is by no means confined to plants, animals also behaving exactly like them in this respect. We shall here mention only one classical example. In Spain there is a breed of poultry known as the Andalusian fowl, consisting of three different colour-varieties, black, blue and splashed white, the variety most sought after by the fanciers being the blue In order to raise as many blues as possible, they always used to breed the blues with blues, hoping thereby to get all the offspring blue, but the result was always disappointing, only half the chicken, on an average, being blue and the others a mixture of blacks and splashed whites as follows —



This result clearly shows that the most desired variety, viz, blue, was not a pure breed but a hybrid of black and splashed white, and that in order to raise blues it was only necessary to breed together the original pure varieties, i e., the blacks and the splashed whites, instead of killing them away as wasters.

REVISION QUESTIONS

384 Show that in the ontogeny of the frog, its phylogeny is recapitulated

385 Arrange the following animals in the order of their evolutionary development Amoeba, Malarial parasite, Paramoecium, the earthworm, Hydra, Obelia, the crab, an insect, a fish, the frog, the whale, the cow, the rabbit, a bird, the crocodile

386 What is a fossil? How does the study of fossils help to show that evolution has been at work in the past?

387 Explain Darwin's Theory of Natural Selection

388. All animals start life as unicellular beings What is the bearing of this fact upon Evolution?

389 If a Paramoecium attains full growth and undergoes binary fission within a space of 24 hours, calculate the number of Paramoecia that would be produced from a single individual in the course of 15 days

390 What is the difference between Variation and Mutation?

391 What is the usually accepted theory of the origin of species? How does it differ from the Theory of Organic Evolution?

392 What are variations? Enumerate a few variations usually met with in man, rabbit, snake, frog, fish, pea-plant, sunflower-plant

393 Give reasons for considering the nuclei to be more important from the point of view of heredity than cytoplasm

394 What is the respective value of the male and the female contribution towards the inheritance of the offspring?

395 Account for the fact that variations are less among wild species than among domesticated ones

396 Why is it that a pure strain of paddy becomes, in the course of a few generations, a mixture of different varieties or even species?

397 What is the advantage of vegetative propagation over propagation from seeds in the cultivation of a mango-garden?

398 Explain the following —the python has a vestigial pelvic girdle and remnants of the hind-limbs, including a pair of claws protruding from the skin on the sides of the cloacal aperture Though man has no tail, he has a coccyx or rudimentary vertebrae of a tail The human embryo possesses paired gill-clefts like a fish The mammalian embryo develops a yolk-sac, though the ovum contains no yolk

399 Recapitulate instances of adaptive modifications you have noted in the external features of the frog, the liver-fluke, the earth-worm and the leech

400 Give instances of inheritance in Mendelian fashion, if any, that you may be familiar with.

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